

The determinants of precarious rural livelihoods in the Mahanadi Delta, India

Tristan Berchoux

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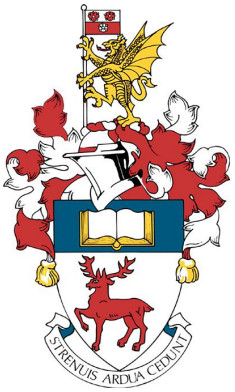

The determinants of precarious rural livelihoods in the Mahanadi Delta, India

by

Tristan Berchoux

A thesis submitted for the
degree of Doctor of Philosophy (PhD)

in the
Faculty of Social, Human and Mathematical Sciences
School of Geography and Environment

2018

ABSTRACT

UNIVERSITY OF SOUTHAMPTON
FACULTY OF SOCIAL, HUMAN AND MATHEMATICAL SCIENCES
SCHOOL OF GEOGRAPHY AND ENVIRONMENT

Doctor of Philosophy (PhD)

The determinants of precarious rural livelihoods in the Mahanadi Delta, India

by Tristan Berchoux

Precarious livelihoods, as a phenomenon that characterises rural household survival strategies, is a serious long-term issue for policies concerned with reducing rural poverty in developing countries. Engaging in precarious livelihood activities, such as daily-wage labour, is a characteristic of rural survival reflecting the continuing vulnerability of rural livelihoods. The increase of the proportion of households engaging in precarious activities in rural areas of many developing countries is not only due to a readjustment of the economy from agrarian to industrial but rather is a persistent phenomenon that reflects the increasing inequalities in rural areas. However, despite the recommendations from rural studies that have shown the importance of multi-level approaches to rural poverty, neither the determinants of precarious livelihoods nor their place-specific context has been well understood. Based on a participatory assessment conducted in rural communities in India, this thesis investigates the determinants of precarious rural livelihoods. After differentiating two levels of livelihood capitals (household capitals and community capitals), the thesis characterises their associations with agricultural livelihood activities by using national census data in a multilevel modelling framework. The thesis then investigates how place influences the drivers of livelihood precariousness by defining typologies of rural communities based on their access to natural resources, social services and productive infrastructures. The associations between agricultural shocks, household capitals and precarious livelihood strategies are characterised for each community type to show how the type of community influences the impact of climatic shocks on livelihoods and changes the direction of the relationships between capitals and livelihood strategies. This thesis brings a new perspective on livelihood studies by demonstrating that community resources and household capitals do not have the same effect on livelihoods. It also demonstrates that the bundle of locally available community capitals influences households' livelihood opportunities and coping strategies, thus influencing the drivers of rural poverty. The thesis identifies that a lack of access to human, financial and social capitals at the household level is associated with vulnerable activities, such as daily-wage agricultural labour. Households located in communities with a greater access to community natural capital are less likely to be agricultural labourers, while proximity to rural centres and access to financial infrastructures are associated with greater chances for households to be landless agricultural labourers. Agricultural shocks drive livelihood precariousness, while access to capitals tends to reduce it. These findings suggest that investment in rural infrastructure might increase livelihood vulnerability, if not accompanied by an improvement in the provisioning of complementary rural services, such as access to rural finance, and by the implementation of agricultural tenancy laws to protect smallholders' productive assets. Overall, this thesis suggests that livelihood studies and poverty alleviation programmes should include community capitals and typologies in their approach to provide place-specific interventions that would strengthen context-specific household capitals, thus reducing livelihood precariousness.

This dissertation has been conducted under the supervision of:

Prof. Craig W. Hutton	Sustainability Science, University of Southampton
Dr. Gary R. Watmough	Socio-Ecological Systems, University of Edinburgh
Dr. Fiifi Amoako Johnson	Social Statistics, University of Southampton
Prof. Peter M. Atkinson	Spatial Data Science, Lancaster University

Composition of the doctoral committee:

Dr. Terry Cannon	Rural Futures, Institute of Development Studies
Prof. Felix Eigenbrod	Applied Spatial Ecology, University of Southampton
Prof. Emma Tompkins (chair)	Environment & Development, University of Southampton

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Declaration of Authorship

I,

Tristan Berchoux

declare that the thesis entitled

The determinants of precarious rural livelihoods in the Mahanadi Delta, India

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Date:

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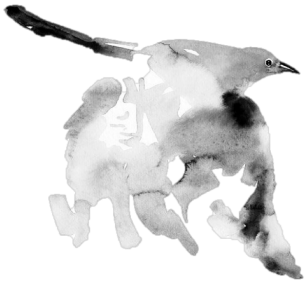


“You never really understand a person
until you consider things from his point of view.
Until you climb inside of his skin and walk around in it.”

Harper Lee

CHAPTER 1 Introduction

Spatial factors, such as environmental conditions, distance to natural resources and access to services shape differential vulnerabilities and influence the impacts of climate change on rural households. Livelihood approaches have become popular amongst stakeholders in development practice or in research settings as conceptual tools to give insights into the way livelihoods intersect with their physical and natural environment. However, despite the recommendations from rural studies that have shown the importance of multi-level approaches to rural poverty, neither the determinants of precarious livelihoods nor the role of place on shaping livelihoods have been well understood. A social geography approach would give to the territory a definition that would enable researchers to grasp how accessibility to resources is built across space. Building on the extensive literature that has looked at the determinants of poverty from a caste and kinship perspective, it appears central to reconnect the different approaches by integrating a territorial approach to characterise if there are significant spatial determinants of precarious livelihoods that could enrich our understanding of the drivers of rural poverty in India. This chapter expands on this statement by introducing the background of the research and discussing the current research gaps that have motivated the study. The motives behind the choice of a study area are then presented and a general overview of the selected study area (the Mahanadi Delta in India) is given, including the geographical characteristics of the delta and the wider socio-economical and environmental contexts it lies within. The highlighted context leads to the identification of research interests, from which a problem statement is formed. Following the formulation of a problem statement, the main aim and objectives of the study are presented. The last section of this chapter discusses the general approach of this research and details the structure of the thesis.

1.1 Research context

Investigating the impacts of climate change on rural livelihoods and rural poverty is a continuing concern within environmental sciences and development studies (Hertel and Rosch, 2010; Olsson et al., 2014). It requires examining the complexities of rural poverty at both individual and collective levels and the cross-scalar intersections between livelihoods and climate change (Laderchi et al., 2003). Repeated exposure to stresses, including climate hazards, can undermine current and future coping capacity, which can lead to shifts from transient to chronic poverty (Olsson et al., 2014; Béné et al., 2016). Spatial factors, such as environmental conditions (e.g. elevation, rainfall, soil quality), distance to natural resources (e.g. forest, wetlands) and access to services (e.g. markets, hospitals, schools) shape differential vulnerabilities and influence the impacts of climate change on rural households (Barrett et al., 2006; Palmer-Jones and Sen, 2006; Okwi et al., 2007; Ansoms and McKay, 2010; Cutter et al., 2014). These spatial factors form a group of interacting services that co-occur in time and space, creating bundles of community capitals (Bennett et al., 2009; Mouchet et al., 2014). The impacts of climate shocks on rural households depend on their coping strategies and livelihood opportunities, and can not only be explained by income-based approaches to poverty (Scoones, 1998; Ellis, 2000a).

Rural households in developing countries rely on a set of livelihood activities in order to increase their capacities to maintain a living and to exit chronic and structural poverty (Carter and Barrett, 2006; Ellis and Mdoe, 2003; Scoones, 1998). The choice of a set of livelihood activities depends on households' access to assets and contributes to their increased resilience or vulnerability to contextual factors, such as internal, socio-economic and environmental stresses (Chambers and Conway, 1991; Ellis, 2000b). While livelihood perspectives have provided a holistic approach to understand the systems in which rural poverty exists, they have been criticised for their lack of operationalisation at multiple spatial scales (Reed et al., 2013). Previous quantitative livelihood studies outlined that the capitals to which households have access (controlled by power relationships of access) determine their livelihood opportunities, the latter being a key driver of poverty (Olsson et al., 2014). However, most of these studies have considered that the determinants of livelihood strategies is constant across space, without considering that there might be community-level factors affecting rural households' opportunities.

The sustainable livelihoods framework only considers household-level assets and capabilities defined as livelihood capitals (Chambers and Conway, 1991; Scoones, 1998), such as natural capital (land, water resources), financial capital (savings, access to credit), physical capital (various productive equipment), human capital (workforce, skills and aptitudes) and social capital (social resources and networks) (Bebbington, 1999; Batterbury, 2008; Scoones, 2015). However, community-level assets, such as environmental conditions (elevation, rainfall, soil quality), distance to natural resources (forest, wetlands) and distance to services (markets, hospitals) are a significant component of rural poverty (Iiyama et al., 2008; Kim et al., 2016) and are thought to have an influence on households' choice of a set of livelihood activities (Barrett et al., 2006; Okwi et al., 2007). Previous livelihood studies have revealed that inequalities in access to livelihood capitals and in livelihood opportunities are spatially dependent and

that they perpetuate poverty and undermine households' ability to cope with external shocks (Allison and Ellis, 2001; O'Brien et al., 2004; de Sherbinin et al., 2008).

This thesis tries to bridge this gap by identifying two levels of livelihood capitals: household and community capitals. It incorporates local knowledge into a quantitative framework to characterise the influence of these two levels of capitals and of climatic stresses on livelihoods. It also provides an analysis of how place affects the determinants of precarious livelihoods, which is crucial for understanding rural poverty and designing effective poverty-reducing interventions, plans and policies (Nielsen et al., 2013; Palmer-Jones and Sen, 2006).

1.2 Study area

The world community is confronted with many risks emerging from climate change, and particularly climate extremes leading to natural hazards. Natural hazards are not affecting geographical regions with the same frequency or intensity and local human and natural systems do not possess the same capacity to respond to a disaster (Dilley et al., 2005). The Working Group II of the Intergovernmental Panel on Climate Change (IPCC) defined the concept of vulnerability as a function of exposure (the character, intensity and frequency of a natural hazard to which a system is exposed), sensitivity and adaptive capacity (McCarthy et al., 2001). The three variables depend on the location of the system: the most vulnerable people live in a place that is highly exposed to climate variability, rely on activities that are highly sensitive to stresses and have a low adaptive capacity to respond to such stresses. Many studies have intended to map climate change hotspots based on the communities that are the most vulnerable to climate variability and extreme events. Although the approaches differ from each other regarding the system studied, the variables assessed or even the type of hazard affecting the system (de Sherbinin, 2013), it appears that some regions are more vulnerable than others, especially northern Africa including the Sahel, the Horn of Africa, Central America, China and Central Asia, in particular India and Bangladesh (Dilley et al., 2005; Giorgi, 2006; Thow and de Blois, 2008; Ericksen et al., 2011; Graw and Ladenburger, 2012). The regions of interest for this thesis are the climate change hotspots mentioned previously, where rural communities are the most vulnerable to climatic shocks.

1.2.1 Selection of a study area

Three agro-ecological zones are considered as highly exposed to climate change, as defined by the following characteristics: the main type of soil, their landforms and their climatic characteristics, with a specific focus on the requirements of crops and the way agricultural systems are managed (FAO, 1996; De Souza et al., 2015): (i) arid and semi-arid regions, which are exposed to a steep temperature increase, to heat waves and erratic rainfall, and in which livestock rearing and agriculture are the main source of income for most people (WFP, 2009); (ii) river basins, which depend on glaciers and snow-packs for water supply and that are greatly exposed to

the increase in temperature, which is likely to lead to an increase in the river water flow, with possible floods as a consequence; and (iii) coastal systems (formed by lagoons, estuaries and deltas), due to their predisposition to floods and to the high density of population living in these areas, whose livelihoods are based on agricultural and industrial production (Ericson et al., 2006; Bucx et al., 2010). In particular, river deltas are typical examples of socio-ecological systems that are extremely sensitive to both anthropogenic and environmental pressures. Deltas are development hotspots, which are highly populated (ten times more than the global average) and make a major contribution to food security (Ericson et al., 2006). As a consequence, deltaic populations have driven dramatic changes in deltas' physical characteristics, which have increased their vulnerability to the impacts of climate change (Syvitski and Kettner, 2011).

1.2.2 Exposure of deltas to environmental stresses

By definition, a delta is a flat and low-lying area located next to a sea or ocean (Wright, 1978) and its landforms are often formed by a combination of rivers. One of the characteristics of deltas is that they are exposed to multiple stressors arising from both terrestrial (such as run-off from rivers, upstream) and marine processes (such as storms, waves or sea-level from oceans, downstream) (Woodroffe et al., 2006), as shown in Figure 1.1. These attributes combined together make deltas one of the most threatened ecosystems in the world (IPCC, 2007; Tockner et al., 2010). Actually, deltas are one of the most exposed ecosystems to effective sea-level rise and floods as a consequence of their low gradients (flat areas), which allow river flooding to spread across lowlands (Mileti, 1999; Wisner et al., 2012). Indeed, they are likely to be inundated to a greater extent in the future, because of storm-induced floods and because they are the draining endpoint of more than 42% of global terrestrial run-off (Ericson et al., 2006). A sea-level rise and an increase of river run-off will also alter water quality because of saltwater intrusion; such a change would have an impact on both environmental (significant changes in the aquatic ecosystems) and human systems (shortages of drinking water and irrigation) (Dasgupta et al., 2014). Coastal and river flooding will lead to land loss because of erosion processes and because of the decrease of fluvial sediment accretion, which happens in almost 70% of deltas (Ericson et al., 2006; Syvitski, 2008). The combination of sea-level rise and river-bank erosion will also generate wetlands loss, which are essential ecosystems for disaster risk reduction (Coleman et al., 2005). Finally, the location of deltas next to oceans leads to their great exposure to cyclones that originate from tropical oceans (Knutson et al., 2010). These natural hazards have a strong impact when they hit one region, causing massive economic damage and life loss (Emanuel, 2003). Moreover, their impact is expected to be greater because an increase of extreme water levels and wave heights is expected, which would induce extreme flooding (McBride et al., 2006).

1.2.3 Rural communities in deltas

Deltas attract a lot of people thanks to their low gradient, plentiful freshwater, transport facilitation and natural resources (Mazoyer and Roudart, 2006). These large flat areas appeal to humans

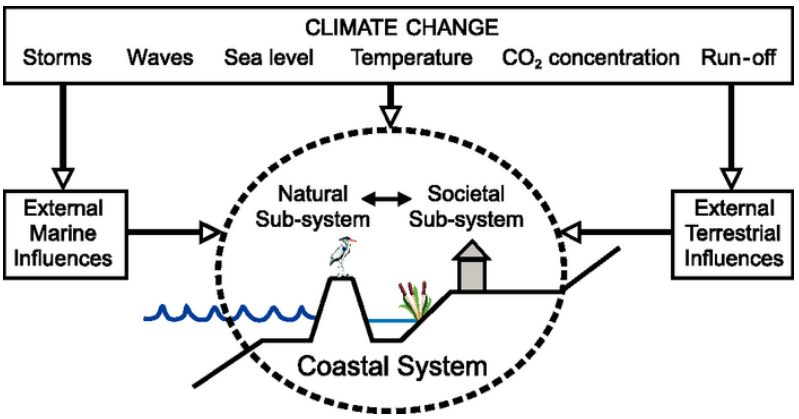


Figure 1.1: Main climatic influences on coastal systems. Deltas are exposed to multiple stressors arising from both terrestrial, such as run-off from rivers, and marine processes, such as storms, waves or sea-level from oceans (figure from IPCC, 2007).

for agricultural and economic development (Nicholls et al., 2007). These regions benefit from fine-grain sediments thanks to their location at the end of river floodplains (Keil et al., 1997). These sediments are predominantly rich in organic carbon, and that is what makes coastal soils the most conducive environment to cultivation (Woodroffe et al., 2006). As a consequence, most of the people who live in coastal plains rely on ecosystem services for ensuring their food security and providing them with economic incomes (Pont et al., 2002). The literature points out that people who live in the countryside of deltas are marginalised because they don't have access to the road network or to markets (Nicholls et al., 2007). Rural livelihoods are thus at risk to climatic shocks as they threaten agricultural production, which is their main source of income. While exposed to a climate variability-induced stressor, such as a natural hazard, these populations have no choice but to migrate to big cities, because of the combination of their marginalisation and the loss of their livelihoods (de Sherbinin et al., 2012). As a conclusion, rural communities located in deltas have a high sensitivity to climatic shocks due to their reliance on the environment for their livelihoods, and a low adaptive capacity because of their marginalisation. According to Smith (2013), they appear to be amongst the communities with the highest levels of vulnerability, as they are located in rural marginal areas who suffer from heavy ecosystem degradation and who are highly exposed to floods and droughts.

1.2.4 The Mahanadi Delta, India

The thesis focuses on the Mahanadi Delta located within the state of Odisha in East India (Figure 1.2). The study area covers all five districts located within 5-meter contour of the Mahanadi river delta: Bhadrak, Jagatsinghpur, Kendrapara, Khorda and Puri. The 5m contour of the delta extracted from Shuttle Radar Topography Mission (SRTM) data[1] is used as a reference for its demarcation (GeoData, 2015).

Table 1.1 provides an overview of the main features of the Mahanadi Delta. The delta covers a coastline of 200 km and is exposed to chronic floods during the monsoon due to the low

[1] Detailed maps of the contours can be found at: `http://www.geodata.soton.ac.uk/deccma/`

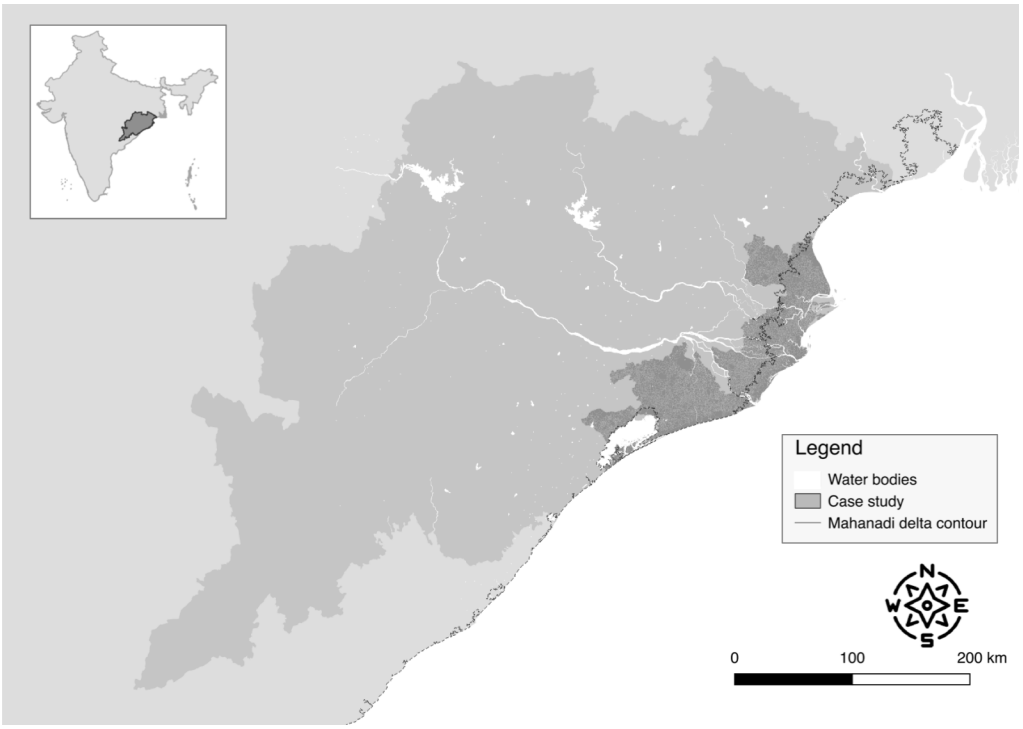


Figure 1.2: Location of the study area. The study area covers all five districts (Bhadrak, Jagatsinghpur, Kendrapara, Khorda and Puri) located within the 5-metres contour of the Mahanadi river delta, extracted from SRTM data.

volumetric capacity of the Mahanadi, Brahmani and Baitarani rivers (Syvitski, 2008). Its location on the North Indian Ocean tropical cyclone track leads to a high likelihood of cyclones to make landfall on the area both before and after the monsoon period. Most households are dependent on subsistence rainfed rice agriculture for their incomes and staple food production, which is highly sensitive to weather-related events, such as droughts and floods. As a consequence, the Mahanadi Delta is one of the poorest regions in India with one of the lowest rates of economic growth and a high prevalence of poverty (World Bank, 2008). In the delta, 46.8% of the population live below the poverty line, of which 90% are subsistence farmers who practice sharecropping on marginal lands, with a very low productivity (Hedger and Singha, 2010). Recent research suggests that more than 30% of rural households in the Mahanadi Delta are landless labour households who are completely dependent on wage employment for their livelihoods (Mahapatra, 2007; Savath et al., 2014a). However, most rural households are composed of marginal and smallholder farmers who have very low income from their land; they represent 60% of the total number of rural households in the delta. In both cases (which accounts for 90% of the rural population), they complement their income with wage employment.

The Mahanadi Delta benefits from a tropical climate; that is to say a hot, moist and sub-humid weather pattern. On average, the 1597 mm of rainfall is spread over 77 rainy days amongst which 80% occur during the monsoon season (from June until September in the south-west and from October until December in the north-east) (Panigrahi et al., 2010). Besides the monsoon period, there are two other meteorological seasons: the winter (from January until February) and the pre-monsoon (from March until May) (Government of Odisha, 2015). Erratic rainfall

Table 1.1: Main features of the Mahanadi Delta. The delta is located in the state of Odisha in eastern India and is formed of three rivers: the Mahanadi, Brahmani and Baitarani rivers

Rivers	Mahanadi, Brahmani, Baitarani
Catchment area (10^3 km^2)	141
Size of delta (10^3 km^2)	5.91
Annual discharge (m^3/s)	1800
Sediment input ($tonnes/yr$)	29.8×10^6
Catchment interventions	Hirakud dam in 1957
Current relative sea-level rise (mm/yr)	3.3
Delta population ($\times 10^6$ $people$)	3.88
Typical livelihoods	Agriculture, fisheries, tourism
Key cities in the delta	Bhubaneswar, Cuttack, Puri
Typical crops	Rice (main crop), wheat, jute, pulses, oilseeds, sugarcane, potatoes, vegetables, spices
Key current land use issues and hazards	Floods, erosion, low dry season availability, water logging, salinisation, surge
Main ecosystems threatened	Mangroves, wetlands
Main sectors threatened	Agriculture, fisheries

is one of the main environmental limitations to agricultural development and is the cause of most of the abiotic stresses in the delta such as: submergence (leads to floods in extreme cases) and moisture stress (leads to droughts in extreme cases) (Samal and Pandey, 2005; Nathan et al., 2008). Figure 1.3 displays the spatial variability of monthly rainfall at various locations across the delta. A delay in the monsoon can be seen in the plot: there is a significant increase of rainfall from May in the eastern part of the coastal region, while the peak is only noticeable in October in the west. The western part experiences less precipitation than the central and eastern regions because of the persistence of low pressure systems over the northwest Bay (Mohapatra and Mohanty, 2006). Temperatures are globally similar across the coastal region, even though the region around the Chilika lake appears to be cooler during the pre-monsoon season. There is also a high variability within the case study concerning the occurrence of climate stresses.

The main risks faced by households in the delta are floods and crop submergence (World Bank, 2008). Heavy rainfall at the upper end and at the catchment areas combined with the convergence of all the major rivers of the state of Odisha in the coastal region are the causes of these flooding events (Beura, 2015). One of the direct consequences of submergence and floods is that they wipe out rice plants at early stages of growth, leading to the loss of the whole production (Samal and Pandey, 2005). During the last 15 years, the coastal districts of Odisha have been hit nine times by floods (Figure 1.4), which makes this type of stress the main climatic risk that threatens livelihoods. Moisture stress and droughts are two of the most important consequences of climate variability because of their direct link with the amount of rainfall in one location. They are recurrent phenomena in Odisha and they, most of the time, lead to crop failure and water scarcity for both cattle and humans (Mohan, 2010). Many of the droughts stem from a monsoon failure, as a result of El Niño events with the warmest sea surface temperature anomalies in the central equatorial Pacific (Parsons et al., 2006). For example, in 2002, a drought hit 30 Districts in the state of Odisha, with an average rainfall deviation of less than 60% (ReliefWeb, 2002). The paddy crop damage was estimated at 68% because of

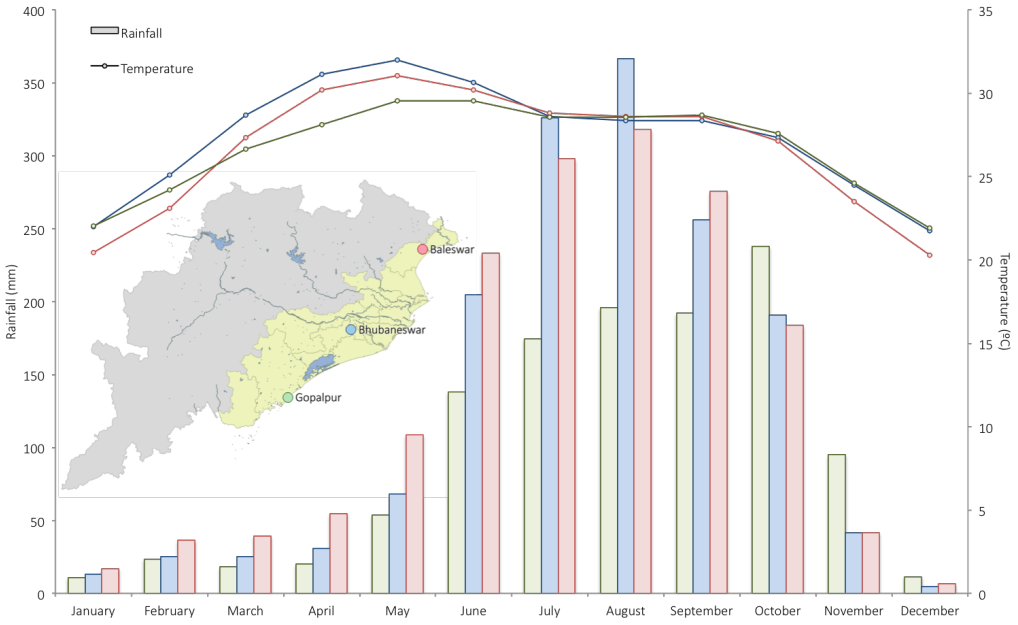


Figure 1.3: Rainfall and temperature in the State of Odisha. Three locations across the delta are considered to show a spatial variability of monthly rainfall. Based on data from Directorate of Agriculture & Food Production Odisha (2014).

the characteristics of kharif[2] crop production to be rainfed. The production of the following cropping season, rabi[3], depends on the amount of rainfall during the end of the monsoon: precipitation during this period reduces moisture stress and helps recharge the ground water table (Mohan, 2010). The Mahanadi Delta is also highly prone to tropical cyclones (Figure 1.4). Since 1999, they have been hit three times by cyclones: the 1999 Odisha Super Cyclonic Storm, the cyclone Phailin and the cyclone Hudhud (IMD, 2014). The 1999 super cyclone caused 9,893 deaths and had an estimated economic damage of 2.5 billion dollars (Chittibabu et al., 2004; IFRC, 1999). The cyclone Phailin led to 21 direct casualties and 17 by consequent flooding in the coastal Districts of the State of Odisha; some 1,154,725 people were evacuated, and about 668,268 ha of cultivated area was destroyed (IFRC, 2013). In 2014, cyclone HudHud caused the loss of 22 human lives, while over 248,00 people in 320 villages were affected (IFRC, 2014).

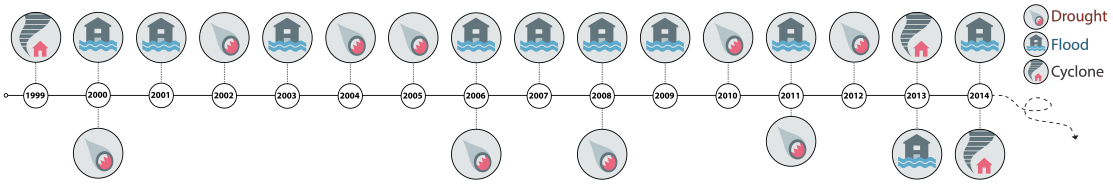


Figure 1.4: Natural hazards in the State of Odisha. Main climate stresses for each year in the State of Odisha, compiled from Government of Orissa (1999); OSDMA (2013).

[2] Kharif crops are grown during the monsoon, from July to October.
[3] Rabi crops are grown during winter, from October to March.

1.3 Research aim and objectives

This section states the problem that this thesis intends to tackle by highlighting the theoretical and practical gaps to be bridged regarding the understanding of livelihoods in the Mahanadi Delta in India. The second part describes in detail the aim of the thesis and the different objectives that this research intends to answer.

1.3.1 Problem statement

Thanks to their location at the end of river floodplains, deltas benefit from fine-grain sediments that are rich in organic carbon, which makes coastal soils one the most conducive to cultivation (Woodroffe et al., 2006; Renaud et al., 2016). As a consequence, most of the people who live in coastal plains rely on agriculture to ensure their food security and to generate economic incomes (Pont et al., 2002). However, deltas are exposed to multiple stressors arising from both terrestrial (such as run-off from rivers, upstream) and marine processes (such as storms, waves or sea-level from oceans, downstream), which are a threat for rural populations relying on agriculture for their livelihoods (Tockner et al., 2010). Moreover, deltas are one of the most exposed ecosystems to climate change, as sea-level rise and an increase in river run-off will lead to increased flooding, alter water quality due to saltwater intrusion, loss of land due to erosion processes and a decrease of fluvial sediment accretion (Ericson et al., 2006; Syvitski, 2008). As a consequence, rural households located in deltas that rely on agriculture are amongst the most vulnerable to climate change, as their main livelihood is highly vulnerable to the projected increase in the frequency of floods and droughts (Wisner et al., 2012; Smith, 2013). Despite the ecological services they perform, the economic value they generate and that they are home to around 500 million people (Giosan et al., 2014), little attention has been paid to deltas as a socio-ecological unit (Wassmann et al., 2004).

The Mahanadi Delta in Odisha, India (Figure 1.2), is a populous delta where livelihood opportunities are negatively affected by environmental stressors, such as floods, droughts cyclones, erosion and storm surges (Ericson et al., 2006; Bahinipati, 2014). The recurrence of environmental stresses has resulted in a loss of income for rural households who are dependent on agriculture for their livelihoods (68% of the delta's population), due to repeated crop failures (Savath et al., 2014a; Duncan et al., 2017). Many of these households have lost their main productive assets, decreasing their ability to cope with the impacts of such external shocks and therefore driving them into chronic poverty in the long term (Christiaensen et al., 2011; Chhotray and Few, 2012; Das, 2012). After losing their productive assets, working members of these households have limited options to move out of poverty, instead becoming agricultural labourers or unemployed (Mosse et al., 2002; Ravi and Engler, 2015). An agricultural labourer is a person who works on another person's land for wages, with no right of lease or contract on the land. According to Williams et al. (2016), unemployment and agricultural labour are seen as the most precarious livelihoods of the rural poor in India. As a consequence, understanding the influence of territory and climatic stressors on the likelihood of households to engage in

precarious livelihoods is central to achieving sustainable development pathways in vulnerable deltas (Dasgupta et al., 2014).

In India, the territory factor has rarely been tackled in social studies looking at the determinants of rural poverty. It has been considered as a background evidence or as an analysis framework that was not worth being examined and even less conceptualised (Benbabaali, 2018). For example, anthropologists and sociologists have argued that territory in India is not one of the primary factors in social organisation but a secondary factor in relation to the two fundamental factors of kinship and caste (Dumont and Pocock, 1957). They further criticise village studies by discussing their propensity to favour the territory factor at the expense of the two fundamental factors of the Indian social structure, which are, according to them, kinship and caste. In their following essay, they question the sociological reality of the "Indian Village" by arguing that village solidarity is an artificially created relationship which is derived from the power relationships between dominant and subordinate castes (Sharma, 1969). According to them, such a vertical solidarity is in fact a form of dependence, while there is a stronger horizontal solidarity based upon kinship within each caste, which goes further than the village extent. Although widely criticised, Dumont's theories have remained influential for a long time, thus leading to a large amount of the Indian literature to neglect territorial dimensions. On the contrary, the territory factor has been widely explored and included in African studies throughout the development of the disciplines of anthropology, sociology and social geography (Francis, 1968). A social geography approach gives to the territory a definition that would enable researchers to grasp how accessibility to resources is built across space (Benbabaali, 2018). Building on the extensive literature that has looked at the determinants of poverty from a caste and kinship perspective, it is central to reconnect the different approaches by integrating a territorial approach to characterise if there are significant spatial determinants of precarious livelihoods that could enrich our understanding of the drivers of rural poverty in India.

The integration of space into economic thinking through the questions of proximity, location, spatial competition, spatial interaction, urban infrastructures and the role of regions has been given sporadic treatment (Derycke and Huriot, 1998). However, the spatial dimensions of development inequalities have been widely discussed in the literature. For example, the notions of "centres" and "centrality" are objects of study for both sociologists and economists (Oliveau, 2005). As such, geographers still have a role to play by bringing a spatial perspectives on social, environmental and economics issues: geography as a discipline looks at explaining the diversity between territories, based on their ecological and societal differences (Pinchemel and Pinchemel, 1988). In particular, an approach derived from the discipline of economic geography, defined as "a field of academic enquiry preoccupied with the geographical scope and scale of economies in the context of economic change, the driving forces behind those changes, and the role of localities in global economic transformation", could help integrate the understanding of the drivers of precarity at a larger spatial extent (Clark et al., 2003).

1.3.2 Research aim and objectives

If precarity characterises and impacts life at an individual scale, social structures mitigate or amplify its consequences. This is the case of caste and kinships in India, which role in driving poverty (or mitigating it) has been widely documented. So how can an economic geographer be useful at this stage? First, providing a geography of precarious livelihoods, a description of their location and underlining the existence of hotspots of precarious livelhioods are relevant to tackle the wider issues of rural development. Geographers work with scales to help visualise the spatial distribution of specific social phenomena, which allows us to understand better their determinants and implications. Moreover, space in general and the territory in particular could play a significant role in determining precarious livelihoods in India, as already suggested by Palmer-Jones and Sen (2006). Livelihood precarity, which is vertically integrated into groups and social structures, is also considered to be incorporated spatially through territorial units, which are horizontally defined. The livelihood opportunities of two households, all things being equal regarding their social integration (caste, kinship), could be different according to their location and especially their environment. In other words, the place where households live is a factor of their poverty and should be analysed as such (Cutter et al., 2008). This thesis proposes to conduct a spatial analysis of precarious livelihood by highlighting the associations between population and territory in the poverty process. This theoretical inquiry is illustrated by using the example of a case study in rural India: the Mahanadi Delta.

This work fits in with a regional approach, aiming at "describing, interpreting, understanding the differentiation and organisation of spaces through a continuous story devoted to the specificity of each ensemble, considered through its internal coherence and its distance to others", as defined in the Universal Geography charter (Reclus, 1886). A regional geography approach relies on the notion that continuous zones can be identified in the landscape. They form territorial systems, which function autonomously from each others, thus justifying to be studied independently to understand how its elements or sub-regions interact with each others. The role of a geographer is to untangle this system's complexity, due to differences of nature, dimensions and duration. This thesis is in line with such an approach and consists in understanding how these territorial systems function and lead to spatial inequalities in terms of livelihood opportunities. The aim of this thesis is to characterise the determinants of precarious livelihoods in the Mahanadi Delta. In particular, it looks at identifying if there are spatial factors (other than caste and kinship) that are associated with precariousness and at characterising their effect on rural households. More specifically, this thesis intends to answer the research objectives presented in Table 1.2.

Table 1.2: Research objectives. Each research objective is detailed with its rationale and the questions that it intends to tackle. Combined together, these research objectives intend to characterise the determinants of precarious livelihoods in the Mahanadi Delta.

Objective 1: to characterise livelihood capitals.
Despite the increasing interest of the sustainable livelihoods framework in the field of international development and in academia and the recent call for the use of mixed-methods approach, there has been little analysis that brings together qualitative and quantitative methods over a large geographical extent. Capital assets are unequally spatially distributed and households' access to them determine their choice of a livelihood strategy. However, the spatial analysis of livelihood capitals is not yet clearly addressed. This first objective intends to spatially characterise livelihood capitals that are determinant for households' livelihood opportunities. The following research questions will be approached:

- which livelihood capitals do households have access to?
- what is the spatial distribution of livelihood capitals?
- what associations exist between livelihood capitals?

Objective 2: to characterise the influence of livelihood capitals on precarious livelihoods.
Livelihood opportunities available to rural households in low and middle-income countries are highly dependent on their access to assets (capitals) both at the household and community levels, which contributes to their resilience to social, economic and environmental stresses. Community-level assets, such as environmental conditions, distance to natural resources and distance to services are a significant component of rural livelihoods and poverty and are thought to have an influence on households' choice of a set of livelihood activities. However, the livelihood studies that have dealt with community-level assets focused on index-based descriptive statistics, without demonstrating their influence on livelihood strategies. Based on the characterisation of livelihood capitals (Objective 1), this objective intends to show the differential associations of household and community capitals with precarious livelihoods. More specifically, it aims to answer the following research questions:

- what is the influence of household capitals on precarious livelihood?
- what is the influence of community capitals on precarious livelihood?

Objective 3: to characterise the influence of climatic stressors on precarious livelihoods.
By definition, climate stresses are climate anomalies that are considered to have a significant impact on rural livelihoods. Although they are expected to increase with climate change, their impact on livelihoods is poorly addressed from a quantitative perspective. Rural households tend to implement strategies in order to cope with such climate stresses, which are often due to weather extremes. However, the links between climate stresses and livelihoods are not fully understood. Following on from the characterisation of the influence of livelihood capitals on precarious livelihoods, this objective intends to characterise the influence of another type of determinant: climate stresses. More specifically, it aims to answer how climate stresses influence livelihood precariousness, declined in the following questions:

- what is the effect of multiple climatic stresses on livelihoods?
- what are the coping strategies that households put in place after facing climate stresses?
- which livelihood capitals buffer the impacts of climate stresses?

Objective 4: to characterise how place influences the determinants of livelihood precariousness.
The multidimensionality of rural heterogeneity can be categorised into community typologies that reflect similar combinations of natural resources, social services and productive infrastructures. Despite the recommendations from previous livelihood studies that have shown the importance of place-based approaches to rural poverty, there have been very few studies that have characterised the role of place on the determinants of precarious livelihoods. This objective spatialises the findings that emerged from the previous objectives by demonstrating how the type of rural community in which households are situated modifies which factors are determinants of livelihood precariousness. In particular, this objective intends to investigate the following points:

- what differentiates communities from one another?
- how does the type of rural community change the relationship between household capital and precarious livelihoods?
- how does the type of rural community change the relationship between climate stresses and precarious livelihoods?

1.4 Research hypotheses

Based on the existing literature, this section reflects on the research hypotheses, with regard to the research objectives presented in the previous section. The synthesis (Chapter 7) will relate back to these hypotheses, in order to elucidate the research's original contribution to knowledge.

Hypothesis 1: two levels of livelihood capitals can be differentiated (household and community), which tend to exhibit spatial associations between them. The SLF only considers household-level assets and capabilities defined as livelihood capitals, such as land, workforce, financial capital, productive equipment, social resources, skills and aptitudes (Chambers and Conway, 1991; Scoones, 1998; Bebbington, 1999; Batterbury, 2008). However, community-level assets, such as environmental conditions (elevation, rainfall, soil quality), distance to natural resources (forest, wetlands) and distance to services (markets, hospitals) are a significant component of rural poverty (Iiyama et al., 2008; Kim et al., 2016; Palmer-Jones and Sen, 2006). Moreover, Lindenberg (2002) mentioned the importance of differentiating community capitals from household capitals in livelihoods studies. This thesis will test the hypothesis that both household and community capitals are important components of livelihood systems and that they follow specific spatial patterns. Moreover, based on the findings from Farrington et al. (1999) who showed that households flexibly combine different capitals and make trade-offs between them to achieve their livelihood strategy and from Raudsepp-Hearne et al. (2010) who demonstrated that trade-offs exist between ecosystem services in diverse landscapes, this thesis will test the hypothesis that there are spatial trade-offs of livelihood capitals.

Hypothesis 2: household and community capitals have a different influence on precarious livelihoods. A broad analysis of the associations between livelihood capitals and livelihood strategies showed that natural and human capitals are positively correlated with farm livelihood strategies, while financial and social capitals are the catalyst for driving non-farm activities (Fang et al., 2014). Overall, it is widely accepted that several factors shape, constrain or influence choices of livelihood strategies (Scoones, 2009; Nielsen et al., 2013). These factors consist of basic material and social tangible and intangible assets that people have in their possession (Scoones, 2009) and the influence of external shocks and stressors (Barrett et al., 2001). Amongst these factors, community capitals (common natural resources, access to infrastructures) were found to influence households' access to more remunerative strategies (Jiao et al., 2017). However, their role in shaping livelihood strategies has only been investigated as a part of households' assets but never as a separate level of livelihood capitals. By separating private good from common-pool resources in the conceptualisation of livelihood capitals, this thesis hypothesises that household and community capitals might play a different role in shaping livelihood strategies, with a special focus on precarious livelihoods.

Hypothesis 3: the recurrence of climate stresses leads to more precarious livelihoods. The repetition of shocks in agricultural production patterns make people adopt new livelihoods as coping strategies (Olsson et al., 2014; Williams et al., 2016). Multiple climatic stressors lead to the erosion of households' assets (McDowell and Hess, 2012), which this thesis hypothesises to be associated with precarious activities. For example, households engaged in cultivation sell off their agricultural land and become agricultural labourers, while households engaged in agricultural labour would stop fulfilling their lease obligations and become unemployed (Christiaensen et al., 2011). However, no work quantitatively assesses distribution dynamics of precarious livelihoods as a consequence of multiple climatic stressors (Olsson et al., 2014). This thesis tries to bridge this gap by testing this hypothesis.

Hypothesis 4: place modifies the extent to which climate stressors and household capitals drive livelihood precarity. Conditions villagers experience in a given place shape vulnerability levels in various ways, demonstrating that vulnerability is often context specific (O 'brien et al., 2007). The investigation of place tells us that vulnerability is variable and situational (Chen and Lopez-Carr, 2015). It reveals the importance of a place-based approach in vulnerability assessments in which local vulnerability is embedded within and influenced by contexts often operating at larger scales but that can also be operating at the individual scale (Cutter et al., 2008; Turner et al., 2003). To date, the only study that looked at the influence of place on the associations between livelihood capitals and livelihood strategies relied on a small spatial extent of six settlements, and showed that place modifies the sensitivity of livelihood strategies to livelihood capitals (Fang et al., 2014). This thesis tests the hypothesis that different combinations of community capitals reflect different underlying types of communities, which influence the drivers of livelihood strategies and rural poverty, and lead to different responses to multiple stressors.

1.5 Organisation of the study

The purpose of this section is to provide a description of the methodological approach used in this thesis to answer the research aim and the different research objectives presented earlier. The first part describes the methodological approach used throughout the study and its iterative process between qualitative and quantitative methods. The final part presents the outline of the dissertation and how the different chapters are linked together.

1.5.1 Overall approach

A core objective of this thesis is to conceptualise rural livelihoods and to investigate what factors drive households into precarious livelihoods. The entry point for such an inquiry is to create contextual knowledge that can be upscaled and replicated to other case studies, but also to participate in the current discussion about theoretical approaches to understanding

people's livelihoods. As such, this work moves away from traditional analyses that favour specific units of knowledge and emphasise specific dimensions of poverty (Shaffer, 2013). This thesis combines a dialogical approach, which focuses on finding locally relevant meanings of the determinants of livelihoods through qualitative methods like focus group discussions and semi-structured interviews, with statistical analyses to upscale the findings to a larger geographical extent. Such an approach is defined as a mixed-methods or Q-squared approach, which is generally understood as a set of methods that add value for understanding and explaining social phenomena (Shaffer, 2013).

The Q-squared approach promotes the integration of qualitative and quantitative methods and has been widely used in poverty analyses. There are different benefits to use a *Q*-squared for the analysis of poverty and livelihoods. First, it can be used to improve the design of research methods such as household surveys (Parker and Kozel, 2007). Second, it enables the researchers to better conceptualise observed behaviours and social structures (Adato et al., 2007), and to highlight directions of causality (Place et al., 2007). Third, the *Q*-squared approach is useful to understand and interpret findings (Parker and Kozel, 2007; London et al., 2007; Sharp, 2007) and to assess their validity (Barahona and Levy, 2007). However, Kanbur and Shaffer (2007) points out that the differences between qualitative and quantitative approaches can lead to misconceptions in the selection of validation criteria and in the conception of poverty adopted, mainly due to epistemology and normative theory tensions. Kanbur (2003) also proposes a typology of differences existing between qualitative and quantitative approaches (Table 1.3).

Table 1.3: Typology of differences between qualitative and quantitative approaches. Differences between approaches can lead to misconceptions in the selection of validation criteria and in the conception of poverty adopted, mainly due to epistemology and normative theory tensions (Kanbur, 2003).

Dimension	Qualitative	Quantitative
Information on population	Non-numerical	Numerical
Population coverage	Specific	General
Population involvement	Active	Passive
Inference methodology	Inductive	Deductive
Disciplinary framework	Broad social sciences	Neo-classical economics

To reduce the tensions between approaches that were raised by Kanbur and Shaffer (2007), an iterative process between qualitative and quantitative methods was put in place in this thesis. Not only sequencing the two methods enriched the research but also clarified the results of the other. This study started with a quantitative component in order to understand the spatial distribution of agricultural livelihoods in the case study and to target the collection of qualitative data (sampling strategy). Then, qualitative methods were used to understand the local perceptions of what households value as livelihood capitals, what it means to engage in precarious livelihoods, and what drives households into precarious livelihoods. The qualitative work also brought new insights about the research questions and led to a re-conceptualisation of the theoretical framework (notably by separating community and household capitals). After the second quantitative analysis based on census data, another qualitative fieldwork was con-

ducted to validate the quantitative findings with key stakeholders. The choice of an integrated methodological approach based on qualitative and quantitative methods was made to obtain a more comprehensive view of the multidimensionality of livelihoods than could have been achieved through either approach alone.

1.5.2 Structure of the dissertation

The thesis that follows is divided into six chapters: literature review, four substantive chapters, and a synthesis. This section gives a brief description of the contents of each of these chapters, which are compiled in Figure 1.5.

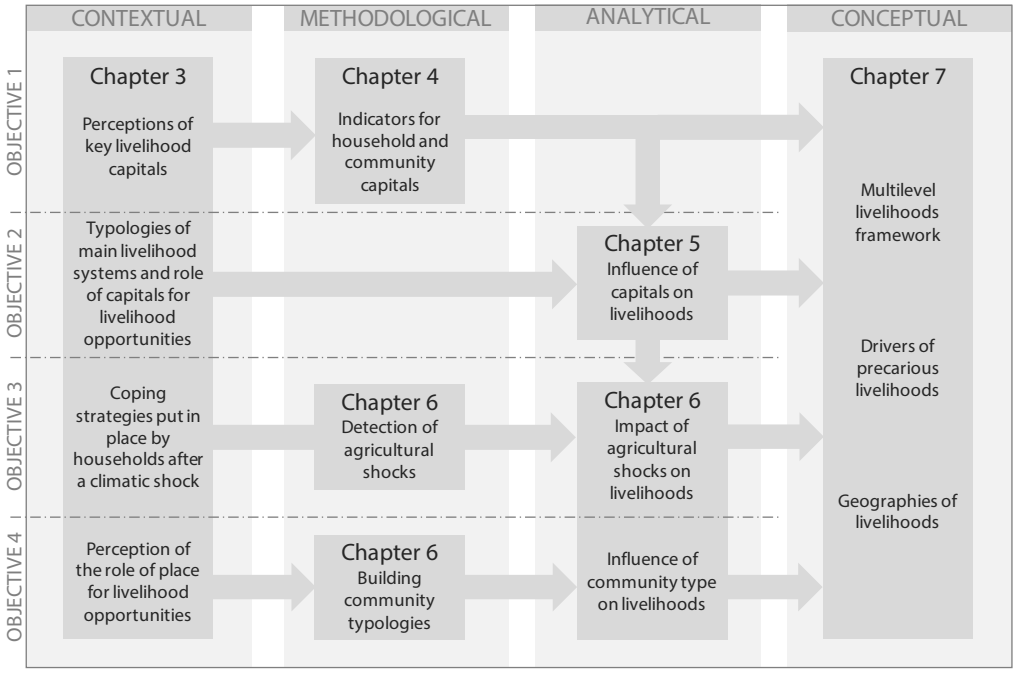


Figure 1.5: Structure of the thesis. Indicates how chapters overlap with the research objectives and gives an overview of the main innovations developed in each part, namely contextual, methodological, analytical and conceptual.

Literature review. Chapter 2 aims to provide the background information required to approach the theoretical concepts and research objectives of this project, as well as introducing key literature about livelihoods in the study site. It first situates the research in the broader environment and development literature, introducing the concept of livelihoods. It then presents quantitative applications of livelihood studies, followed by a political economy analysis of livelihoods in India, before moving on to providing an overview of the literature on rural livelihoods in the study site.

Substantive chapters. There are four substantive chapters to this thesis. Each chapter using different methods and having different objectives, the choice is made to present each of them loosely in the format of an academic journal paper. The results are preceded by an introduction

and review of the methods utilised, leading to some unavoidable but limited duplication between chapters. Throughout each of these four substantive chapters runs a discussion into the significant areas, implications, and limitations of the work being presented. Each chapter contributes in part to answering the framing and conceptual aspects of all the research questions presented earlier.

Chapter 3 presents the results of rapid rural appraisals examining communities' perceptions of their access to livelihood capitals and livelihood opportunities, and the coping strategies they put in place after facing external shocks. This chapter provides context to the later analysis and background as to which capitals are determinant for livelihood opportunities and which coping strategies are put in place by households after facing a shock (Objectives 1, 2, 3 and 4).

Chapter 4 integrates the findings from Chapter 3 into a series of quantitative indicators to highlight the spatial distribution of livelihood capitals and to characterise the existing associations between them (Objective 1). After building an indicator-based conceptualisation of livelihood capitals at both community and household levels, it examines the spatial patterns and differentials in access to livelihood capitals across the study area and then characterises the associations between livelihood capitals.

Chapter 5 presents the development of a statistical model used to characterise the collective influence of household and community capitals on precarious livelihoods, focusing on the case of landless agricultural labourers. This chapter builds upon the quantification of livelihood capitals (Chapter 3 and 4) to identify household and community capitals that are relevant and robust for examining the susceptibility of communities to landless agricultural labour, which is an indicator of chronic poverty. In doing so, it shows the differential impacts of household and community capitals on determining precarious livelihoods (Objective 2).

Chapter 6 demonstrates how the type of rural community in which households are situated modifies the impact of climatic shocks and access to livelihood capitals on precarious livelihood strategies (Objectives 3 and 4). A typology of rural communities in the Mahanadi Delta is defined and the associations between climate extremes, household capitals and precarious livelihood strategies are then characterised for each community type.

Synthesis. Chapter 7 provides an overall conclusion to the thesis. It summarises the findings to answer the research objectives, outlines the limitations of this work and discusses implications for future research.

CHAPTER 2 Characterising livelihoods: a literature review

This chapter provides the background information necessary to formulate and meet the objectives laid out in Chapter 1 with due regard to previously conducted research. Running throughout the chapter is a structured investigation into rural livelihoods, including the theoretical background of livelihood studies, their different components, and their qualitative and quantitative applications. The chapter begins with a wider discussion of the frameworks to understand rural poverty in the context of environmental change, focusing on their main concepts and limitations. As part of the review process, this first section outlines the selection of an analytical framework for the thesis. The following section discusses the theory and current debates behind the Sustainable Livelihoods Framework, including some of the methodologies and proxies proposed in the academic literature to quantify its components. The chapter goes on to present some applications of livelihood studies, with mention of the literature that has used the Sustainable Livelihoods Framework through a quantitative lens, with a particular focus on the methods they used and the research questions they answered. An overview of the literature that has looked at the trade-offs between livelihood capitals and at the influence of livelihood capitals on livelihood strategies is also included in this section, followed by a discussion on how livelihoods have been profiled in previous research. The following section focuses on the political economy of rural livelihoods in India. After presenting in details the Indian caste system and its consequences for power relationships, it goes on by analysing the political economy of India's pro-rural policies before discussing the issues of land-tenure, which has been demonstrated to be a key determinant of poverty in rural India. The chapter ends with an overview of rural livelihoods in the Mahanadi delta, including an overview of poverty issues and of the different types of livelihood activities that households put in place.

2.1 Frameworks to understand rural poverty

According to Nunan (2015), there are different approaches to investigating the relationships between rural poverty and the environment, either through a livelihood perspective or through wellbeing. In this section, the two main frameworks tackling livelihoods and wellbeing are presented, and a justification of this research framework is given after providing a short summary of the different approaches.

2.1.1 Livelihood perspectives

The purpose of this section is to review the concept of rural livelihoods. It begins by giving insights on the concept of household livelihood analysis and into the context in which it is integrated. The following section reviews the different components of livelihood systems and its underlying conceptual theories and frameworks.

2.1.1.1 Livelihoods thinking: concept and definitions

The concept of livelihoods has been developed in the middle of the 1980s as a reaction to the oversimplifying way of approaching poverty in the development discourses (Scoones, 1998; Ellis, 2000b). As Scoones (1998) points out, such studies relied on income-based measures of poverty that were leading to top-down approaches regarding the basic needs of rural dwellers. However, only few rural households rely on one single income-generating activity (Rakodi and Lloyd-Jones, 2002). They tend to have a diversity of activities, and to have access to capitals that are usually not taken into account, such as ecosystem services (Walpole et al., 2000). The concept of livelihoods tries to bridge this gap of understanding and allows a new approach of development, led by the communities themselves (Chambers, 1983). It also helps to assess households in their environment and to study their interactions. Such linkages are very important in rural areas where people rely on the environment for food and for their economic sustainability (Pont et al., 2002), and so it is essential to understand them to develop relevant actions for poverty alleviation. For De Haan and Zoomer (2005), household studies and especially livelihood analyses are a better approach to tackle poverty. As a summary, Appendini (2001) gives an overarching objective of the livelihoods approach: it is to develop more effective methods to give support to people and communities to improve their daily lives and to achieve their needs. A summary of the main definitions of the concept of livelihoods and an overview of the main notions it calls up are provided in this section.

Before proceeding to examine the definitions of the livelihoods approach, it is necessary to characterise the base-unit of this concept: the household. For Scoones (1998), the household is considered as the reference unit for decision-making. He argues that decisions are made singularly, with the objective of maximising the household's welfare. The latter is subject to a diversity of income-earning opportunities and a set of resource constraints, and designing its

strategy is part of the decision-making process of this unit. Such definition is only based on the decision-making process, which can be sometimes unclear. On the contrary, Ellis holds the view that

> "A household is conceived as a social group that resides in the same place, shares the same meals and makes joint or co-ordinated decisions over resource allocations and income pooling" (Ellis, 1998).

This definition still considers the decision-making process as a key element to characterise one household. The concept of livelihoods focuses on the location of households, on what they have, on their needs and their interests (Chambers, 1983). Although there is a consensus on the fact that livelihoods look at the ways and means of making a living, many different definitions have arisen with the development of this approach, led by various authors. The most widely accepted definition is the one proposed by Chambers and Conway (1991) that describes livelihoods as the system that gathers capabilities, assets and activities of one household in order to achieve its means of living. However, although most of the authors agree on that definition, it has been improved with the development of the literature on this subject, detailed below. Scoones (1998) defines a livelihood by its capacities and capabilities to achieve a means of living. For this author, livelihoods and sustainability are indivisible. Thus, Scoones gives the first definition of sustainable livelihoods (Scoones (1998):5):

> "A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base."

One of the main critics of Scoones's definition is that it does not consider the households' ability to have access to the different resources. De Haan and Zoomer (2005) claim that the conceptualisation of access is a gap in this explanation of livelihoods. The definition proposed by Ellis tries to include this concept (Ellis (2000a):10):

> "A livelihood comprises the assets (natural, physical, human, financial and social capital), the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household."

With the definition proposed by Ellis, the concept of livelihoods becomes one of the "multiple" capital approach, by unpacking the households' assets into five different capitals: natural, physical, human, financial and social.

2.1.1.2 Sustainable livelihoods framework

Figure 2.1 shows a synthesis diagram that summarises the framework used to characterise rural livelihoods. One household has access to different assets; this relationship can be modified by the institutions, social networks and organisations at both local and national levels. The assets to which the household has access are called capitals, and are transformed into outcomes (improved food security, increased well-being) by the households' members through a different panel of activities. The combination of one household's assets and activities is called the livelihood system. The transformation of capitals by the panel of activities leads to different livelihood pathways, which eventually bring outputs to the households that will feedback into its capitals.

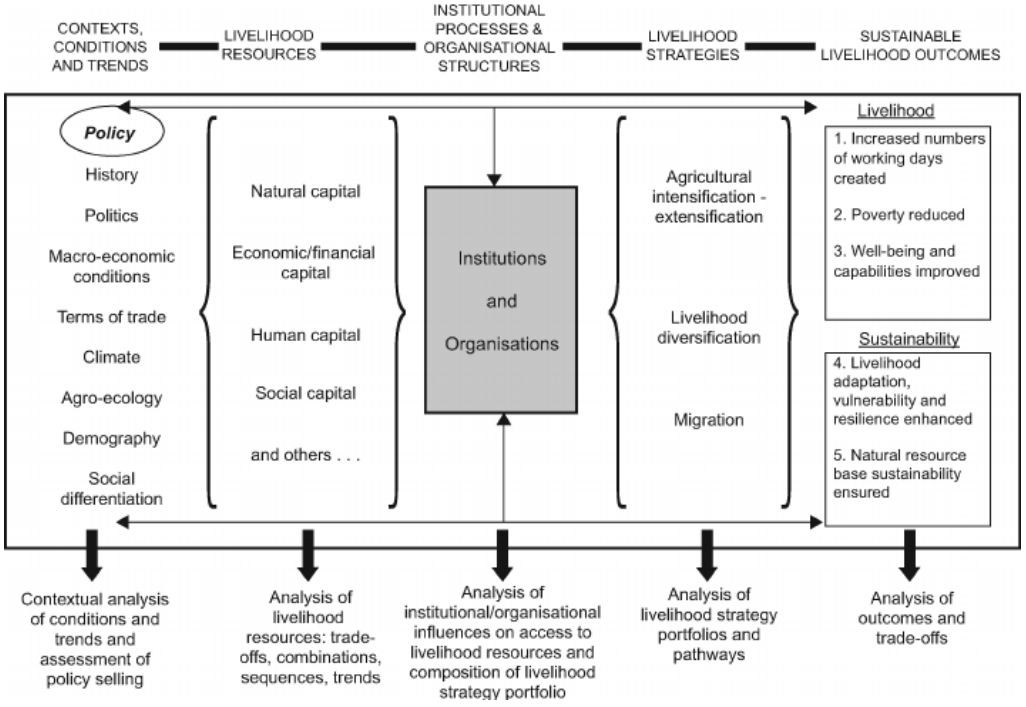


Figure 2.1: Sustainable livelihoods framework. A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base (Scoones, 1998, 2015).

As a summary, the livelihood approach aims to understand the differential capability of rural families to cope with crises, for example, natural hazards such as floods or droughts (Allison and Ellis, 2001). To do so, the framework that has been developed allows for the identification of main capitals and the characterisation of the interactions among them (Benson and Clay, 2004).

2.1.1.3 Multiplicity of methodological approaches

There is not a unified approach to the concept of sustainable livelihoods and the methodology depends on the institution implementing it. However, they all focus on a common goal: a

sustainable social development (Valdés-Rodríguez and Pérez-Vázquez, 2011). The purpose of this section is to review and compare the different approaches of sustainable livelihoods that are used by the international community. Some institutions such as the World Bank, the World Food Programme, the FAO, the Asian Bank or the European Commission use the concept of sustainable livelihoods in their work, based on one of the mainstream frameworks. The approach of these institutions is not addressed in this section because they use one of the frameworks presented hereinafter (Krantz, 2001; Hussein, 2002; Serrat, 2008; Valdés-Rodríguez and Pérez-Vázquez, 2011).

Department for International Development. The definition of a sustainable livelihood for the Department for International Development (DfID) was presented for the first time in Carney (1998). This institution adopts the definition from Chambers and Conway (1991) and is often presented in a diagram (Figure 2.2). However, instead of the concept of transforming structures, a new notion appears: policies, institutions and processes (PIP). This is supposed to describe the complex range of issues that are linked with the governance environment in which livelihoods evolve (Hobley, 2001). However, the different departments of DfID usually adapt the concept according to their approach of one problem. For example, political capital and gender issues are sometimes added to the framework (Hussein, 2002). There are different main principles in the DfID's approach: it is poor-people centred (people livelihoods and their dynamics are at the centre of the framework), and holistic (it reflects the integrated nature of people's strategies and lives). The way of addressing livelihoods is also dynamic (evolution of strategies over time) and conducted at a multi-level scale (multiple actors, different levels of aggregation) (Krantz, 2001). As a conclusion, the main difference with the other approaches can be found in the way of addressing the structures and processes that affect livelihood strategies. The DfID approach gives an emphasis on this element, by distinguishing public structures, private, markets and social relations (Carney, 1998).

United Nations Development Programme. According to Krantz (2001), the United Nations Development Programme's sustainable livelihoods approach provides a conceptual framework in order to reduce poverty in a sustainable way. It comprises the means, activities, properties and goods that one household uses to achieve its means of living. With this definition, this international institution agrees with the concept of livelihoods exposed by Scoones (1998). However, UNDP's approach differs from the notion developed by Ellis (2000b). Although the institution introduces similar assets to the concept, such as natural, social, human and physical capitals, it does not consider financial capital but an economic asset for which the definition is broader as it adds the variable of employment. Also, a sixth capital is added: the political asset that comprises the participation of households in society. According to the UNDP (1997), sustainability is reached when the household is able to recover from sudden stresses or changes, but does not compromise options, either now or in the future. This approach of sustainability focuses on the use of assets by the household, which has to be economically effective, and socio-ecologically equitable. Moreover, the UNDP identifies two types of capitals

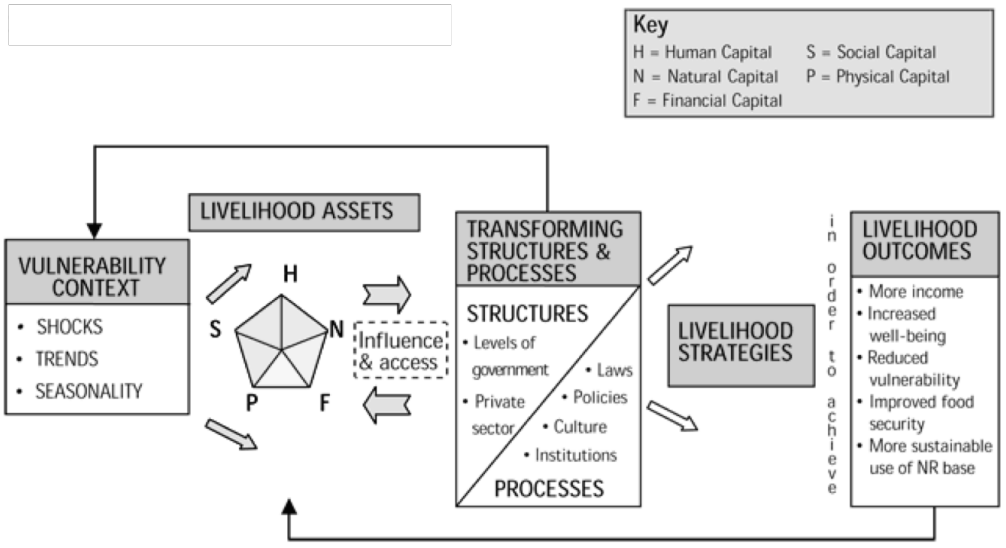


Figure 2.2: DfID sustainable livelihoods framework. Definition of a sustainable livelihood for the Department for International Development (DfID) as presented for the first time in Carney (1998).

that influence the capacity of households for their livelihoods. These capitals are divided into tangible (stocks and physical resources) or intangible (claims and opportunities), and their effect is interdependent (Krantz, 2001). As a conclusion, one of the main elements that distinguishes the UNDP's approach from the others is the political focus and the impact of national policies on livelihoods.

International Fund for Agricultural Development. The International Fund for Agricultural Development (IFAD) has started to use the sustainable livelihoods approach since 1999, and the first time it appears in an official document is in the 2002 Strategic Framework (2002-2006) (Hussein, 2002). IFAD's approach is based on the work of DfID, but it incorporates several changes to its framework: although the DfID's approach claims to be people-centred, the IFAD considers that the framework is not poverty-focused (Hamilton-Peach and Townsley, 2006). IFAD's new approach intends to address the above issue by placing the poor at the centre of the diagram and then arranging the other elements that interact with them. The social factors of processes that influence the relations between people and the other elements of the framework are highlighted. Those social processes include gender, age, class and ethnic group of the people considered. Moreover, a sixth asset has been added to the initial framework - personal assets - in order to take the factors that affect the choices of households into consideration, such as their internal motivations, their spiritual side or even their desire to engage in political activity (Hamilton-Peach and Townsley, 2006). Also, based on the work of Hobley (2001), this approach tries to represent two levels of institution with which households interact and are the users of: the service provider agencies (whose aim is to implement policy measures) and the enabling agencies (whose aim is to make decisions on priorities and strategies in dealing with poverty). Furthermore, IFAD's framework also unpacks the original concept of "processes", by explicitly highlighting its terms. As an example, markets are emphasised because of their importance in

determining the ability of households to convert the accessible resources into assets. Similarly, politics (power relations within society, different from policy), culture (social norms) and rights (regarding the household's institutional environment) are also highlighted in IFAD's framework. The framework differs from the other livelihoods framework by changing the semantic of some elements. For example, the term "strategies" is replaced by "actions" to show that households are not necessarily willing to do some activities, but they do it anyway in order to realise their aspirations (Hobley, 2001; Hussein, 2002; Hamilton-Peach and Townsley, 2006). As a conclusion, the IFAD's approach tries to make the original concept of livelihoods more precise by unpacking its different elements and having a less sequential arrangement of the framework.

CARE. The notion of livelihoods has been used by the international non-governmental organisation Cooperative for Assistance and Relief Everywhere (CARE) since 1994. The core concept of CARE's approach derives from the definition of Chambers and Conway (1991), combined with the "Household Livelihood Security" framework, which is used for programme analysis, design, monitoring and evaluation Krantz (2001). The fundamental elements of the framework sticks to the original concept with households possessing capabilities, having access to assets and conducting economic activities; altogether they define the household's livelihood strategy. Although this framework seems to be very similar to the previous ones, it actually promotes a right-based and access to basic needs approach (Carney et al., 1999). Moreover, it is important to highlight that the Household Livelihood Security framework does not consider natural resources nor infrastructures belonging to the community as capitals but as parts of the external context (Drinkwater and Rusinow, 1999). Physical capital and financial capital are no longer considered as separate assets and are aggregated in the term "economic value". Two new forms of capital are added, making explicit some terms that are embedded within the capitals in other frameworks: the capabilities and access to available resources. Finally, another major difference is that livelihood outputs feed back to the context, whereas they feed back to the household's capitals in the other frameworks. To conclude, as pointed out by Krantz (2001); Lindenberg (2002); Valdés-Rodríguez and Pérez-Vázquez (2011), CARE's approach focuses more on the capacities and capabilities of the households at a micro-level. It also appears that their approach is based on a socio-economical analysis of households, as natural capital is not considered as part of the assets even if it is a key component for rural livelihoods.

2.1.1.4 Limits of the concept and links with poverty

According to Barrett and Reardon (2000), one major drawback of livelihoods perspectives is that their indicators for sustainable livelihoods are very broad, diffusive and are all different in scope. He holds the view that, as a consequence, this framework can only be used for a qualitative approach because it appears very difficult to quantify livelihoods. A quantification of livelihoods would not be able to be compared because livelihoods are processes, similar to a production function. This interpretation contrasts with that of Nielsen et al. (2013) and Savath et al. (2014b) who have quantified livelihoods based on households' assets and activities. However, such

an approach was criticised as being subjective, in the sense that the authors decide which indicators to include in each capital (Scoones, 2009). In summary, although aspects of livelihood quantification have been criticised, some quantitative studies have been able to shed new lights on livelihood perspectives (e.g. Ansoms and McKay, 2010). Finally, Barrett and Reardon (2000) suggest that the concept lacks one essential part of the rural economy: it ignores the effect of prices and their risks.

Before proceeding to the summary of livelihoods, it is important to discuss the links that exist between livelihoods and poverty. The term poverty is generally understood to mean the inability to secure a minimal standard of living (Sen, 1975, 1981). This term can be opposed to security of existence, which means people have a sustainable access to food and socio-economical security that enables them to overcome shocks. Concerning livelihoods, if the different capitals are becoming weak, inefficient and unsustainable, households will find their vulnerability increasing. Thus their ability to meet their basic need will erode (Venkatesh, 2006). In other words, levels of vulnerability are increasing when capitals are decreasing because they lack a buffer to face shocks (including climate hazards) and thus will suffer most from repeated shocks, especially if the recovery time is short (Olsson et al., 2014).

2.1.2 Wellbeing approaches

Interest in wellbeing analysis has grown during the last couple of decades within development studies, thanks to the influence of the capabilities approach (Nunan, 2015). The concept is also strongly associated with psychology and anthropology, which were the first disciplines tackling wellbeing. The following sections give an introduction to the concept of wellbeing and then present the two main frameworks used within development studies.

2.1.2.1 Concept of wellbeing

The concept of wellbeing intends to embrace all of the dimensions and experiences of poverty by taking into account the diversity of how poverty is experienced (Gough and McGregor, 2007). For example, poverty can be portrayed as a lack of income but it can also be seen as a form of social exclusion. Gough and McGregor (2007) define the term 'wellbeing' as "a state of being with others, where human needs are met, where one can act meaningfully to pursue one's goals, and where one enjoys a satisfactory quality of life". The main characteristic and source of interest of a wellbeing approach is its focus on people's priority and perspectives, with a positive connotation that reflects the complexity of people's lives. The following sections present two conceptual approaches to wellbeing: the "Millennium Ecosystem Assessment Framework" and the "wellbeing in developing countries approach".

2.1.2.2 Millennium Ecosystem Assessment Framework

The Millennium Ecosystem Assessment was oriented towards the identification of linkages between ecosystem services and human wellbeing with the objective of influencing policy (Millennium Ecosystem Assessment, 2005). Figure 2.3 shows the conceptual framework that was informed by the assessment. The two central elements in the framework -ecosystem services and wellbeing- influence and are influenced by drivers of change that can be direct or indirect. Four types of ecosystem services are highlighted in the framework: provisioning; regulating; cultural; and supporting. Each one of these ecosystem services has an effect on one of the aspects of human wellbeing, such as health, access to basic material to achieve a good life, security and social relations. Direct drivers of change are driven by the aspects of human wellbeing and encompass societal changes that can be demographic, social, political or cultural. They have an effect on direct drivers of change, which are related to the environment but can be either anthropogenic (e.g. environmental planning) or climatic (e.g. climate change, natural drivers). This framework provides a way of understanding the implications of ecosystem services on human wellbeing and thus enables the identification of trade-off between ecosystem services and their associated effects on human systems.

2.1.2.3 Wellbeing in developing countries approach

In this approach, wellbeing is seen as a combination of: (i) the resources that a person has access to; (ii) the needs and goals they are able to achieve with those resources; and (iii) the processes in which they engage (Gough and McGregor, 2007). Two dimensions of wellbeing are tackled in the framework, each one being divided between objective and subjective aspects (White, 2010). The first dimension of wellbeing is "the material", which concerns assets, welfare and standards of living. Its objective aspects consist of income, assets, consumption, employment and livelihood activities, while its subjective aspects include satisfaction with wealth and the assessment of present standard of living compared to others and to the past. The second dimension is "the relational", which consists of social relations, access to public foods, capabilities, attitudes to life and personal relationships. Some of its objective aspects include identities, violence and security, access to services and amenities, networks, environmental resources, household structure and composition, education, health, care and love relations. Its subjective aspects include perceptions of safety, access to services, environmental quality and health levels but also concern self-perception, faith and trust.

2.1.2.4 Limits of the concept

Both of the wellbeing approaches reflect the complexity of people's lives in a holistic way. However, the conception of wellbeing is difficult to define because of the different understandings of its meanings (Nunan, 2015). Moreover, the subjectivity embedded in its dimensions are influenced by knowledge and relations, which might lead to a biased understanding of people's

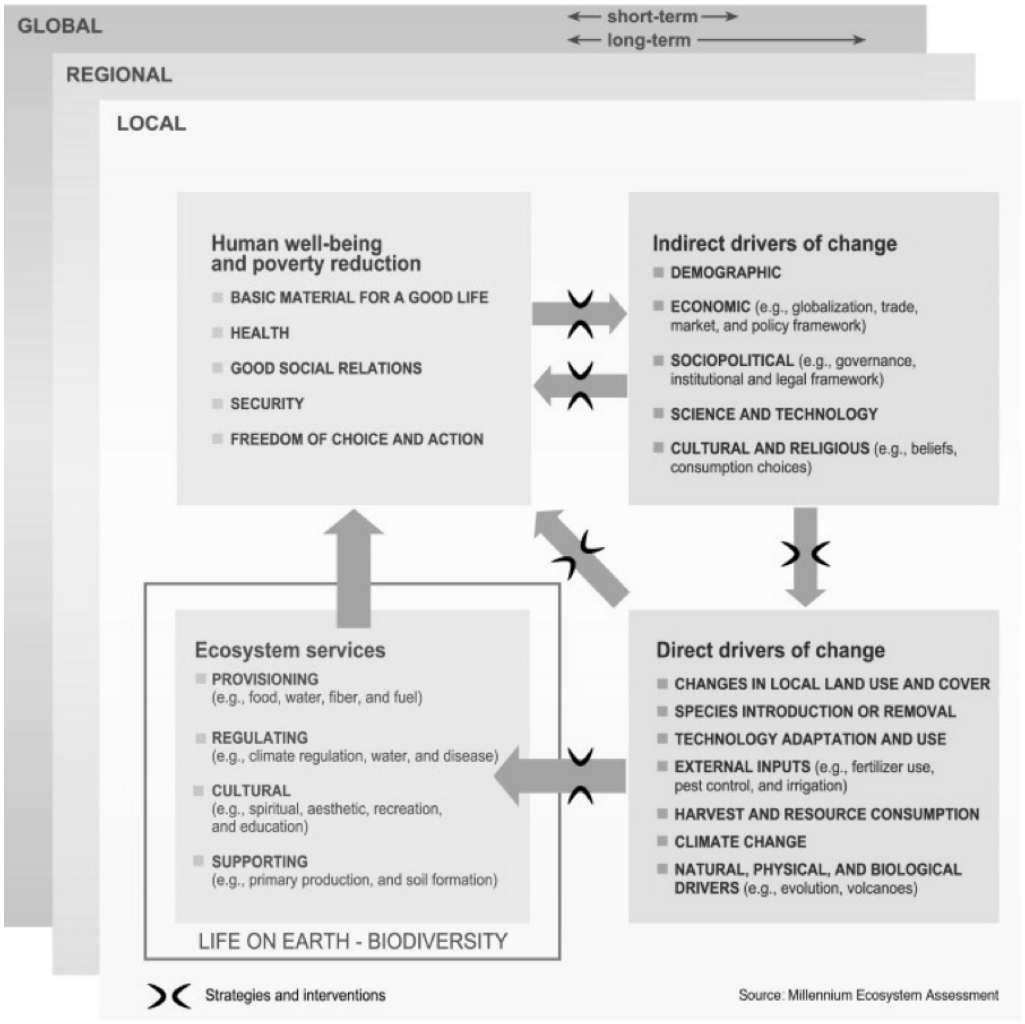


Figure 2.3: The Millennium Ecosystem Assessment conceptual framework. The framework focuses on how changes in ecosystem services affect human well-being, how changes in the ecosystem may affect people in future decades, and what types of responses can be adopted at local, national, or global scales to minimise the anthropogenic drivers of change (Millennium Ecosystem Assessment, 2005).

perspectives (Coulthard et al., 2011). Fisher et al. (2014) is also critical of the capacity of wellbeing approaches to take into account social differentiation and suggests an adapted framework that put "access to and control over" ecosystem services at its centre.

2.1.3 Comparison and selection of an analytical framework

Livelihood and wellbeing approaches have similar roots in the concept of capability, with a holistic focus on what people have rather than what they do not, unlike poverty approaches. They also aim at understanding people's lives in their broad context and try to make sense of the complex interactions that exist between them. However, their methodological approaches differ from each other, with wellbeing frameworks providing a deeper understanding about people's lives by taking into account their perceptions and feelings. Although both approaches need a multidisciplinary lens, wellbeing frameworks need to draw on psychology to understand

how people view their own life (Gough and McGregor, 2007). On the other hand, livelihood approaches are used to highlight key trends and typologies by generalising the interactions between people's lives and their environment.

Returning to the aim of this research, it appears that both approaches can be used to investigate the determinants of precarious livelihoods and their interactions with climatic shocks. However, considering the extent of the study area, it is necessary to select an approach that can give a rapid assessment of the general trends at stake and that can be upscaled through a quantification of its qualitative elements. It appears that a livelihoods perspective is more suited to this aim. It appears difficult to use the deeper understanding offered by wellbeing approaches (i.e. people's perceptions) with quantitative modelling without conducting a specific survey. As discussed in Chapter 1, this research is designed to be reproducible and usable by public stakeholders, thus focuses on data widely accessible that do not provide the details needed to conduct a quantitative analysis based on a wellbeing approach. As a conclusion, the sustainable livelihoods approach both satisfies the specific focus of this research on livelihoods and its methodological constraints. The following sections present the approach in greater details by unboxing and analysing its different components.

2.2 Unboxing the sustainable livelihoods framework

As was pointed out in the presentation of livelihood approaches, households have access to different assets that can be called capitals. Livelihood capitals are then transformed by the households' members into outcomes through a different panel of activities. It is now necessary to decompose those different components and to explain in detail what concepts they encompass. This section provides such an analysis, starting with the livelihood capitals, then the activities and finishing with the livelihood outcomes.

2.2.1 Context

Context influences all aspects of livelihoods and cannot be seen as an exogenous single factor. They are all-encompassing, and the combination of these structural processes influence livelihood systems at all levels (Scoones, 2015).

Political economy and sociology. Relationships between states, markets and citizens are central to livelihoods, with domination relations sometimes deeply rooted within societies (Fraser and Dougill, 2011). A political economy and sociology of livelihoods must theorise macro-economic conditions (forces of globalisation, influence of neoliberal capitalism), the role of state and elites, society's institutions and organisations, and their relations between each other to appreciate the structural, contextual and historical drivers that shape household's opportunities and constraints to get access to capitals (Batterbury, 2008). Those processes rely on socio-economic underlying factors, such as gender, age, wealth, ethnicity and class (Mehta

et al., 1999). However, these determinants being both contextual and spatial, it is essential to embed them into a deeper political economy and sociology analysis.

Shocks and stresses. According to Von Braun et al. (1992), there are different types of risk that rural poor face, and to which households are exposed unevenly (Table 2.1). By definition, stresses are recurrent events or long-terms trends that put pressure on the household's livelihood system. On the contrary, shocks are unexpected events that have an adverse impact on the household's livelihood system. Natural risks encompass climate variability, natural disasters and climate change. They affect crop production (crop failure) and livestock rearing (loss of livestock) and are particularly a threat to landless farms labourers and to smallholders with little income diversification and limited access to improved technology such as improved seeds, fertiliser, irrigation, pest control. Natural shocks undermine the natural, physical and financial capital of households while stresses lead to a decline in natural resource stocks and changes in vegetation, water and hydro-meteorological systems, thus undermining future livelihood capitals. Human risks threaten entire communities, but especially households that cannot afford preventive or curative care and vulnerable members of these households. They undermine human and financial capitals (illnesses, injuries, deaths), which lead to a shift in livelihood strategies and the distress sale of assets (coping strategies). Stresses from health sources can be at the household level (malnutrition, frequent illness) or at the community level (inadequate health systems, lack of access to health facilities). Social risks are mostly faced by vulnerable groups such as women, and especially those without education, female-headed households, children at weaning age, the elderly and ethnic minorities or lower castes. Households living in communities located in war zones and areas of civil unrest are the most likely to face risks related to political stability, and especially remote and marginalised communities. Finally, economic risks can be of different type, but the main impact they have on households concern an increase of food prices. Such shocks would affect smallholders who are highly specialised in commercial farming of export crops and who are deficit food producers, small-scale pastoralists and any household highly dependent on imported food, such as poor net food-purchasing households, wage-earning households and informal sector employees.

2.2.2 Livelihood assets, resources and capitals

To put in place livelihood strategies and pursue their livelihoods, households depend on their access to basic material and social assets, also called capitals (Johnson, 1997; Scoones, 1998). Although the term "capital" embodies a multitude of concepts and has been source of criticism because it reduces the complexity of livelihood processes to economic units and suggests that they are comparable, most of the literature refers to capitals as the bundle of assets household have access to (Scoones, 2015). A further definition of assets is given by Bebbington (1999) who describes them as what people have but also what they believe, identify with and feel. This author categorises assets based on their action, and distinguishes three different types of action: (i) instrumental (making a living); (ii) hermeneutic (making living meaningful); and (iii)

Table 2.1: Type of shocks and stresses faced by poor rural households. Stresses are recurrent events or long-terms trends that put pressure on the household's livelihood system, while shocks are unexpected events that have an adverse impact on the household's livelihood system (Ellis, 2000a).

Type	Source	Shocks	Stresses
Natural	Natural disasters or adverse weather patterns	Flood, cyclone, drought, excessive rainfall	Decline in natural resource stocks, climate change
Human	Adverse health outcomes suffered by household members	Illness, injury, death	Frequent or lingering illness, inadequate health systems, malnutrition
Social	Breakdown of social networks, demands made by social networks, social obligations	Dissolution of social networks due to disasters or access to schemes	Social celebrations, discrimination or stigma, life cycle events (births, weddings, deaths), demands on household assets by social network
Political	Adverse political events and trends	Strikes, disputed elections, violence, destruction	Political dispute, inadequate public services, lack of access to legal system
Economic	Adverse events and trends in the national or regional economy	Sudden price inflation for basic staples	Price inflation, poor economic infrastructures

emancipatory (challenging the structures used to make a living). A variety of definitions of the term "access" have been suggested, the first definition suggested by Ribot and Peluso (2003) being the most appropriate for this research: access is seen as a "bundle of powers" defined by the social and political-economic contexts, rather than the "bundle of rights" notion of property. While the capitals listed below contribute to the reduction of poverty and to the accumulation of wealth, they are not themselves capital. Their accessibility, scope and resilience are mediated and shaped by social relations of class, caste, and gender (O'Laughlin, 2009). A conception of society as stratified, with different aspects characterised by different powers and emergent properties informs the ways in which the "units" (individuals and households) and categories (caste and class) are conceived and operationalised (O'Laughlin, 2002). Such a conception relies upon an acknowledgement that these categories or social roles are internally related. In other terms, the actions that one person can do or the assets that one person can access are partially dependent on their relations with others and on the much broader social and material context in which they are located (Downward and Mearman, 2007). In this section a working definition for each capital is proposed. After reviewing the scientific literature available to identify indicators that have been repeatedly referred to as relevant measures of rural people's livelihood assets, examples of how these capitals could be differentiated into community and household capitals are discussed. Moreover, processes that mediate and shape the accessibility, scope and resilience to these capitals are discussed in the light of each capital's context and social relations.

Natural capital. Natural capital refers to the physical environment and to the natural resources accessible to the household that can be used to expand or enhance their livelihoods (Chambers and Conway, 1991). According to Scoones (1998) and Farrington et al. (1999), it is composed of the natural resource stocks (such as land, soil, water, air, forests) and environmental services (such as hydrological cycle, pollution sinks). Natural capital in the livelihood framework is strongly linked to the concept of ecosystem services (Costanza et al., 1997). However, ecosystem services are not necessarily similar at the community or household level. For example, regulation of floods by mangroves or provision of natural pesticides thanks to biodiversity are meaningful ecosystem services at a community scale, but they are difficult to grasp at a finer scale (De Haan and Zoomer, 2005). The concept of environmental entitlements developed by Leach et al. (1999) explains how natural capital is seen from a livelihood perspective: "environmental entitlements refer to the alternative sets of utilities derived from environmental goods and services over which social actors have legitimate effective command and which are instrumental in achieving wellbeing".

In most studies, agricultural-relevant indicators were used to proxy this capital. The most commonly used indicator that has been used is farm area per household, which enable households to diversify their agricultural systems and might enable them to increase their livelihood outputs. Although this indicator has been only used at the household-level, it appears that considering the total area of farmland of the community could highlight different dynamics that are relevant for livelihoods. As shown by previous studies, synergies are created between households concerning agricultural practices but also marketing opportunities in communities where there is a great area of cropland (Banks, 1999; Marschke and Berkes, 2005). As such, it appears that natural capital brings different types of instrumental and emancipatory services to households depending on the level considered (i.e. meso- or micro-level).

One of the negative proxy that was the most commonly used is elevation, high altitude limiting agricultural production due to climatic controls such as temperature, precipitation and air pressure, which restrict the growth of the majority of cultivated species (Singh and Hiremath, 2010; Jansen et al., 2006; Donohue and Biggs, 2015). However, there is no consensus about such a proxy, as elevation might have an indirect positive income effect because it stimulates more remunerative livelihood strategies (Fang et al., 2014). Similarly, some authors used average slope in the construction of natural capital, considering that high topographic gradients limit agricultural production and accessibility, due to erosion and irrigation-related problems (Minot, 2000; Benson et al., 2005; Singh and Hiremath, 2010; Donohue and Biggs, 2015), although this hypothesis is only valid for locations with a high percentage of land made up of very steep slopes (>30%) (Okwi et al., 2007). Due to its strong direct impact on agricultural production, soil quality was widely used in the quantification of natural capital (Minot et al., 2002; Kristjanson et al., 2005; Place et al., 2006; Erenstein et al., 2007; Donohue and Biggs, 2015), while Jansen et al. (2006) and Erenstein et al. (2010) used it in combination with farm size as a way to quantify potential agricultural production. Finally, annual average precipitation was also a widely used indicator for natural capital, high precipitation enhancing agricultural production (Kristjanson et al., 2005; Jansen et al., 2006; Erenstein et al., 2007, 2010; Donohue and Biggs, 2015). However,

slope, soil quality and rainfall are indicators of crop suitability or indirect drivers of agricultural production. Potential crop yield, which is a direct indicator of agricultural production, would be a more suited indicator to control for these factors and can be derived from remote sensing (Sakamoto et al., 2013; Duncan et al., 2015, 2017). Following the definition of natural capital by Scoones (1998), availability and distance to the closest fresh water resource (river/lake) were included in most studies that quantified natural capital, with the underlying hypothesis that access to water for consumption and productive uses is a major factor in rural livelihoods, especially those dominated by small-holder agricultural activities. Proximity to a lake, a river or the sea also gives households the opportunity to diversify their livelihood activities and their source of food through fishing, shrimp farming or kitchen gardening (through manual irrigation). Surprisingly, none of the quantitative livelihood studies used the availability of forest resources in the quantification of natural capital, whereas it is widely acknowledged as an important source of income for rural households thanks to the exploitation of timber and non-timber products (Babulo et al., 2008; Walelign, 2016). Overall, despite their relevance at the household-level, the previous indicators are examples of capitals that operate at a meso-level scale. This thesis argues that they should be considered as community capitals rather than household capitals, as their level of governance and the synergies they create operate at a community-level. However, it is important to highlight that access to such assets (especially those at the community-level) is mediated and conditioned by social relations of class, caste, and gender. For example, livelihood opportunities created by proximity to a lake or forest might not be beneficial to all households within a community. Bundle of powers are key mediators of the ability for household to access one asset. In India, the hierarchical caste system prevailing in rural areas might prevent household from lower castes to benefit or use some community amenities or resources (Das, 2001).

Human capital. Human capital refers to the knowledge and capabilities possessed by the individuals who live in one household. It is composed of the skills, knowledge and ability to labour (good health and physical capabilities) (Scoones, 1998). Besides knowledge and capabilities possessed by individuals, it also encompasses the intangible character traits (ambition, drive, persistence, etc.) that determine how effectively individuals apply their knowledge and capabilities to livelihood activities (Niehof and Price, 2001). Key indicators of human capital are access to education, access to health services, access to sanitation and clean water but also access to adequate amounts of nutritious food.

The vast majority of livelihood studies include dependency ratio as a proxy for workforce availability (Jansen et al., 2006; Jansen and Pender, 2006; Soltani et al., 2012; Fang et al., 2014). It is defined as the ratio between the number of people who are working over the number of dependent people in on household. Previous studies have demonstrated that it is one of the main factor impacting livelihood strategies and poverty levels (Mosse et al., 2002; Nguyen et al., 2017). In addition to dependency ratio, Jansen et al. (2006) include the average number of men per household in their definition of human capital. They argue that at the household level, the number of male adults is a key determinant of the decision to go for seasonal migration with

greater wages than daily-wage labour. Rural female literacy has frequently been recognised as an important factor in reducing poverty and a key indicator for future education and health behaviours (Erenstein et al., 2007, 2010; Erenstein, 2011; Watmough et al., 2016). In particular, maternal education in the form of the proportion of women over 7 years old who could read and write with understanding in any language has been identified as a driver of social benefits and of restructuring of societies (Walter, 1999).

A better access to education is also an asset for the household, as it helps breaking the circle of poverty and improves poor people's livelihoods (Janvry and Sadoulet, 2001). Different indicators to proxy access to education can be found in the literature: Benson et al. (2005); Kristjanson et al. (2005) use physical distance to the closest education facilities, defined as number of facilities per 1000 people. This thesis argues that in fact, such a proxy is an indicator of the community's access to social services, as it does not take into account the fact that households might face barriers that prevent them from benefiting from such an amenity (which can be due to social relationships or financial barriers). Donohue and Biggs (2015) use school enrolment, defined as the proportion of school-aged children attending primary and lower secondary, which encompasses better the final access that households have to education. Finally, access to health facilities and sanitation infrastructures is a key element towards better health and thus improved livelihoods (DFID, 1999). Distance to health facilities and sanitation infrastructures have been used as a proxy for health: proximity to health facilities decreases human loss and work incapacity, thus decreasing the vulnerability of human capital (Benson et al., 2005; Kristjanson et al., 2005). Similarly, this is a proxy for community amenities that does not represent households' access to human capital. Availability of water infrastructures is also a proxy for health status to be included in the human capital (Benson et al., 2005; Kristjanson et al., 2005), despite some authors considering it as part of the physical capital (Belcher et al., 2012; Donohue and Biggs, 2015). The availability of safe drinking water is considered as vital for human well-being and prevents the emergence of diseases that would weaken human capital (Cairncross et al., 2010; Curtis et al., 2011). Moreover, without access to water, long periods are spent in non-productive activities such as the collection of water (DFID, 1999; Belcher et al., 2012). In this case, two levels can be highlighted: the availability of safe-drinking water at the community-level (which is conditioned by households' ability to access it) and the proximity to water resources at the household-level.

Physical capital. Physical capital refers to the economic infrastructures and assets that enable one household to pursue its livelihood. According to Carney (1998) and Serrat (2008), it is composed of infrastructures, tools and technology which are essential for the pursuit of any livelihood strategy. Infrastructures include transport, roads, vehicles, secure shelter, buildings, water supply, sanitation, energy and communications. Tools and technology include equipment for production, seeds, fertilisers, pesticides and traditional technology. This thesis argues that infrastructures should be differentiated from tools and technology as they are different types of goods: infrastructures are common-pool resources or public goods that should be considered as community capitals (i.e. access to common-pool resources is conditioned by bundle of powers);

tools and technology are private or club goods that should be considered as household capitals.

Based on the hypothesis that transportation infrastructures improve working opportunities and access to amenities, most studies include a proxy of accessibility in the construction of physical capital, such as road density (Grootaaert et al., 1995; Pender et al., 1999; Staal et al., 2002; Kristjanson et al., 2005; Erenstein et al., 2007) or travel time to closest paved road or urban centre (Babulo et al., 2008; Erenstein et al., 2010; Soltani et al., 2012; Bhandari, 2013; Donohue and Biggs, 2015). Similarly, access to a market increases the potential for agricultural growth and improve working opportunities, which both drive rural development (Grootaaert et al., 1995; Pender et al., 1999; Staal et al., 2002; Kristjanson et al., 2005; Erenstein et al., 2007, 2010; Belcher et al., 2012). In developing countries, the availability of power supply for agriculture and commercial use determines households' capacity to engage in remunerative livelihood strategies (Ellis, 2000b). It is a two-level capital that enables households to increase their productive capacity (Belcher et al., 2012): the availability of electricity at the community-level does not mean that households have access to electricity (and vice-versa). Similarly, investments in irrigation, which are done either by public institutions (community capital) or by households (household capital), can mitigate climate variability and extremes and secure agricultural production (Erenstein et al., 2007, 2010; Belcher et al., 2012; Huai, 2016). Finally, access to transport and agricultural equipment (e.g. tractors, animal carts, fertilisers) enhance households' capacities to conduct productive activities and is a positive proxy of household physical capital (Jansen et al., 2006; Ansoms and McKay, 2010; Erenstein et al., 2010; Soltani et al., 2012; Bhandari, 2013; Fang et al., 2014; Liu and Liu, 2016).

Financial capital. Financial capital is defined as the economic capital base necessary for the pursuit of a livelihood strategy (Scoones, 1998). It includes cash, savings, formal and informal credits, remittances, pensions, insurances and any protective asset that is held as a store of value and that can be sold if the household faces an external shock (crop failure, death, disease, wedding). Protective assets include cash, jewellery and livestock if the household is not involved into livestock rearing (otherwise it is considered as a productive asset, thus physical capital) (Kent and Dorward, 2012; Chena et al., 2013).

Much of previous studies have included distance to the closest banking facilities or credit societies in their definition of financial capital, considering the availability of formal banking facilities or credit societies as a key indicator of households' capacity to hold and expand their financial capital (Kristjanson et al., 2005; Claessens, 2006; Erenstein et al., 2010; Donohue and Biggs, 2015). However, being able to physically access formal banking facilities does not mean that households have the capacity to use financial services (because of social barriers for example) and thus should be considered as a community capital. Access to formal credit is particularly a problem for household from lower castes and the poor when trying to meet unforeseen expenditure, and difficulty in accessing formal finance has resulted in a heavy reliance among poor rural households on informal finance, mostly moneylenders and shopkeepers (Jones, 2008). Households' access to financial services can be picked through the ratio of households having access to financial services, either formal or informal (e.g. de Sherbinin

et al., 2008; Ansoms and McKay, 2010; Soltani et al., 2012; Fang et al., 2014). Ownership of protective assets, such as livestock, serves as an important store of savings for households, which can be converted into cash or exchanged for goods or services when needed, especially during times of hardship, and even if it is not their primary purpose (Dovie et al., 2006; Erenstein et al., 2010; Bhandari, 2013). Value of assets has also been widely used in the construction of financial capital, including the value and condition of housing (Fang et al., 2014) and the value of farmland (Erenstein et al., 2007; Bhandari, 2013; Donohue and Biggs, 2015; Liu and Liu, 2016). All the studies reviewed so far, however, suffer from the fact that they do not take into account households' level of indebtedness. Actually, access to financial services becomes a negative asset when the debt-to-capital ratio is greater than one (Basu, 2006; Sidhu and Gill, 2006; Taylor, 2011; Japelli et al., 2013).

Social capital. The initial and most common understanding of social capital consists of "the social resources (networks, social claims, social relations, affiliations, associations) upon which people draw when pursuing different livelihood strategies requiring coordinated actions" (Scoones, 1998). Although very different uses of the term can be found in the literature, the definition of social capital through a livelihood lens is widely accepted: it refers to any social network connection of the household and its quality, that is to say its reciprocity and trust or its quality to do resource-sharing (Scoones, 2015).

Some authors have argued that increased population density can be seen as a social asset in rural areas where accessibility is key as a higher density increases the possibility of kinship ties and access to community services (Donohue and Biggs, 2015). However, it has also been demonstrated that low population density is conducive of trust, thus improves social capital (Collier, 2002). The proportion of ethnic minorities has also been used as an indicator of social capital in various studies (Erenstein et al., 2010; Bhandari, 2013; Nielsen et al., 2013; Savath et al., 2014b; Donohue and Biggs, 2015), based on the hypothesis that members of disadvantaged classes or castes suffer from social, economic, educational, political and religious exclusion. However, the most important factor for social growth is the absence of minorities, which are considered as a driver of social tensions (Krishna and Uphoff, 1999; Collier, 2002). Prevalence of communication services such as telephone, transport and postal has also been used as proxies for the density of social networks (Krishna and Uphoff, 1999; Erenstein et al., 2007) as they are endogenous to social interaction (Collier, 2002). Finally, the availability of community-level amenities such as recreational facilities (e.g. cinemas, stadiums, playgrounds) increases the possibility of kinship ties (Krishna and Uphoff, 1999) and goes hand in hand with participation in associations, groups and clubs (Erenstein et al., 2010; Soltani et al., 2012; Fang et al., 2014), although the participation of households being conditioned by their social relationships of gender, class and caste.

2.2.3 Livelihood activities and strategies

Livelihood activities can be seen as the actions that households take to produce outcomes (Winters et al., 2001). They involve the use of a single asset or a set of assets to produce outputs: to meet people's consumption requirements and aspirations and to invest in assets and activities for the future (Dorward et al., 2009). In rural settings, livelihood activities can be classified as "on-farm" (agriculture, livestock, aquaculture, forestry) and "off-farm" (commerce, manufacturing and other services) (World Bank, 2008). Livelihood strategies refer to the combination of activities in which individuals engage based on their access to livelihood capitals (Scoones, 2009), with the assumption that individuals will adopt the strategies which best preserve and improve their asset base (Erenstein et al., 2007). The activity portfolio of one household is distinguished from its dynamic pathway, the first one grouping the activities undertaken by one household's members, the latter capturing its overall strategy (Dorward et al., 2009).

Activity portfolio. Sen (1975) notes three aspects of employment outputs: income (a wage for the employed), production (employment providing a consumable output) and recognition (where employment provides recognition for being engaged in something worthwhile). In rural areas, employment can be refined into two types of activities (World Bank, 2008): (i) on-farm, which are related to self-employed farming or agriculture; and (ii) off-farm activities, which are defined as any activity other than farm-related (e.g. manufacturing, shopkeeping, transport, etc.).

On-farm activities are the main livelihood activities of rural households in agrarian societies, with their outputs used for subsistence and/or commercial purposes (Bhandari, 2013). Subsistence agriculture consists in cultivating staple crops for the household's own consumption (cereals and pulses). However, many households sell part of their harvest to get "fast cash" (need for cash rapidly to cover current expenses or recover a debt) but they usually contract a loan or go on migration later to buy the complementary food, necessary for their food security (Diniz et al., 2013). On the other hand, commercial agriculture consists in cultivating non-staple high-value crops that farmers sell to traders or cooperatives. Livestock rearing gives outputs used for self-consumption or for trade (in the market or to cooperatives) that can be of two types: meat production or dairy, the latter mostly for households located near outlets. Fishing activities are of two types: aquaculture, which requires investment; and capture fishing (sea, lakes, rivers), which is much more common as it does not require must investment (Fisher et al., 2014). Forestry brings together extractive activities of timber products (wood) and non-timber forest products (NTFP), such as seeds, roots, leaves, fruits and flowers.

Off-farm activities play an important role in livelihood diversification and adaptation to external shocks and can be of three main types (Bhandari, 2013): (i) salaried employment; (ii) self-employment; and (iii) temporary employment. Salaried employment, a type of labour work where the employee regularly receives a regular predetermined income, is quite uncommon in rural areas of developing countries and mostly consist of public employment (government, administration, teachers) or private services (bus drivers, cooks, construction) (Reardon, 1997;

Niehof and Price, 2001). Emigration or skilled long-term migration (when members go on long-term migration -more than a year- outside of their region) falls into that category, and is put in place by households with a strong human capital with skilled individuals (mostly men). Self-employed persons work for themselves and earn their incomes through a business activity (retailers, wholesalers, equipment owners, bus operators, private entrepreneurs and other service providers), which ensures them to get greater and more frequent incomes than unskilled labourers, although it does not guarantee them to get regular wages. Seasonal labour migration is a type of temporary labour that does not guarantee incomes from one season to another, however it does guarantee a wage for one season (Mosse et al., 2002; Adger et al., 2002). This type of migration is unskilled and can be considered as "distress" migration because the money earned is mostly used for household expenses (mainly food) or to repay loans (Black et al., 2011; Parida, 2016). Another type of temporary employment is daily-wage labour, which does not give any guarantee to the household and is most of the time an informal agreement between the employer and the employee. This type of unskilled work is available nearby the worker's community and is mostly sought when one household have no other option or when they lack physical or financial capital. Examples of daily-wage labour include agricultural labour, construction work and junk collection, amongst others.

Livelihood strategies. According to Dorward et al. (2009), four overall types of livelihood strategies can be distinguished. The *stepping-up* strategy represents households who have an increase in income flow and asset stocks and who use their current incomes to invest in productive assets to expand their ongoing activities as a way to improve their livelihoods. Some of their members often have a permanent employment: (i) in the public sector (government administration, teachers, etc.); (ii) in the private sector (drivers, plumbers, etc.); or (iii) self-employed (businessmen). Regular wages are then invested into the productive assets of the household (agricultural inputs, equipment, vehicles, other tools) to improve and secure their livelihoods. Households who are "stepping-out" follow a strategy of investment into assets that will enable the household to move into different activities that should lead to higher or more permanent returns. Such a strategy is qualified as adaptive (Dorward et al., 2009) and enables households to spread risk through diversification. As an example, incomes from agriculture can be invested into training or into migration funding to diversify their portfolio of activities and get higher incomes in the future (Ruiz-Pérez et al., 2004). Strategies falling into the "hanging-in" category represent households who are engaging in activities to maintain their actual level, without investing into any new productive assets nor any alternative livelihood perspective. In such a strategy, incomes are used to buy agricultural inputs (on a same basis than previous seasons), to repay loans, to buy food or to cover daily-life expenses. After facing a shock, these households put in place coping strategies that try to minimise the costs of the adverse event and to ensure that future livelihood capacity is not seriously reduced. The last category is "dropping-out". Households in this category usually have a weak human capital, with disabled members, elderly or are female-headed. Because of their lack of physical and human capital, they only engage in daily-wage activities and incomes are used for daily-life expenses only, with the only perspective of surviving.

2.2.4 Livelihood outcomes

Outcomes reflect what households aim to achieve based on the strategies they put in place. Laderchi et al. (2003) highlight four different conceptual approaches to livelihood outcomes: (i) the monetary approach focusing on utility maximisation; (ii) the capability approach focusing on one's freedom to live a "valued" life (Sen, 1993); (iii) the social exclusion focusing on marginalisation and deprivation (Clert, 1999); and (iv) the participatory methods approach focusing on internally-defined indicators of outcomes, wealth and wellbeing (Chambers, 1997). Drawing of these previous studies, Scoones (1998) draws a typology of outcomes and summarises them into five types of livelihood outcomes that are conditioned by the amount of income earned by the household: (i) increased numbers of working days created; (ii) poverty reduced; (iii) well-being and capabilities improved; (iv) adaptation, vulnerability and resilience enhanced; and (v) natural resource base sustainability ensured. The "increased numbers of working days created" relates to the ability combining livelihood strategies to create employment for a certain portion of the year, either on- or off-farm, as a wage labour system or subsistence production (Sen, 1981). The "poverty level" is a key criterion in the assessment of livelihoods, for which various indicators can be used to create a "poverty line" measure based on income or consumption levels (Baulch and Hoddinott, 2000). Alternatively, poverty can be measured relatively by using inequality coefficient measures, such as the Gini index (Gastwirth, 1972). The notions of well-being and capability encompass more than the material concerns of food intake or income (Scoones, 1998). This well-being approach to poverty and livelihood analysis allows people to define themselves the criteria which are important, through participatory approaches (Chambers, 1994, 1997). This may result in a range of "sustainable livelihood outcomes" criteria, including diverse factors such as self-esteem, security, happiness, stress, vulnerability, power, exclusion, as well as more conventionally measured material concerns (Chambers, 1989). This typology was later reshaped into a set of five more specific outcomes that grouped "working days" and "poverty" together and included food security (DFID, 1999): (i) more income; (ii) improved food security; (iii) increased well-being; (iv) reduced vulnerability; and (v) more sustainable use of natural resources. The first livelihood outcome falling under the categories "more income", "increased numbers of working days created" and "poverty reduced" is a monetary indicator that represent the remaining income left once basic needs are secured. This money is then invested by households to improve their living conditions and to buy protective and productive assets. Food security has to be understood as the level of self-sufficiency in the production of the main staple crop; it is a survival stage that households want to achieve and that mostly depends on their access to agricultural land, the availability of workforce within the household and the household's capacity to engage in income-generating activities (Carney, 1998; Devereux, 2001).

2.2.5 Coping mechanisms

Coping strategies are defined as the temporary adjustments made by households in their livelihood systems in response to shocks, which can be external (natural hazards, movements in

markets, changes in policy environment) or internal (health problems, changes in household composition, social rituals) (Carney, 1998; Scoones, 2015). Three different types of coping mechanisms can be highlighted based on their reversibility (Chen and Dunn, 1996; Mutangadura et al., 1999; Kabir et al., 2000): (i) reversible mechanisms, defined as temporary activity shifts or the disposal of protective assets; (ii) erosive mechanisms, defined as the disposal of productive assets, such as land; and (iii) destitution, such as going unemployed or going into distress migration. Reversible mechanisms can be observed when some members take wage labour or migrate to find paid work (temporary activity shift) or when using self-insurance mechanisms, such as selling protective assets (Chen and Dunn, 1996). Self-insurance mechanisms encompass the following strategies: using monetary savings, selling livestock such as goats or cows, bonding or selling jewellery and other assets, contracting a loan from formal or informal institutions, reducing human capital investments (health and education spendings) and shifting to cheaper food consumption patterns (by reducing food quantity or quality). Erosive mechanisms are usually implemented in response to heavy shocks or persisting stresses and undermine households' productive capacity. Strategies falling under such erosive mechanisms are: selling equipment, tools, or animals used for farming, borrowing to moneylender, selling, exchanging land or reducing the amount of land farmed, and in the most sever cases the reduction of food consumption and other essential expenditures. In the case of disposal of agricultural land, this leads to a long-term livelihood change, as households shift from cultivation to agricultural labour (Himanshu et al., 2013). The last category of coping mechanisms comes as a last recourse for the household and indicates its destitution, with households' members becoming unemployed and starting to beg or going for permanent out-migration under distress (Bhatta and Aggarwal, 2015).

2.3 Applied livelihood studies

Livelihood perspectives have dominated rural development thinking and practices for the past twenty years, but have been recently criticised for their lack of innovation (Scoones, 2015). Key points of criticism have been their inability to address and quantify emergent issues such as geographical shifts in the rural economy and their difficulty to be upscaled through a quantitative application. This section reviews the literature of applied livelihood studies that are relevant to the main research objectives of this thesis (Chapter 1). First, it examines existing studies that have used the sustainable livelihoods framework through a quantitative lens. Second, it gives an overview of the literature that has applied this framework to understand trade-offs between capitals. Then, it presents the findings of previous research that have characterised the sensitivity of livelihood strategies to livelihood capitals. Finally, the section presents how livelihoods were profiled in previous research, before reviewing the literature on livelihood dynamics and rural transitions.

2.3.1 Quantitative livelihood studies

One major theoretical issue that has dominated the field of livelihood studies for many years concerns the use of quantitative methods to understand rural livelihood and their dynamics. This section reviews the main questions answered by these studies and their methods. Quantitative livelihood studies can be divided into two main categories on the basis of the level of analysis they are looking at: (i) micro-level studies that aim at profiling livelihoods; and (ii) meso-level studies that mainly aim at building asset-based livelihood indices.

Micro-level studies. Almost every paper that has been written on the quantification of livelihood strategies at a micro-level includes a section relating to household clustering (Table 2.2). Various methods have been developed to profile livelihood strategies, the main difference between them can be found in the selection of variables for clustering: some authors relying on households' portfolio of assets (e.g. Orr and Mwale, 2001; Ansoms and McKay, 2010; Fischer and Chhatre, 2015), activities (e.g. Bhandari, 2013; Savath et al., 2014a) or a combination of both (e.g. Brown et al., 2006; Jansen et al., 2006; van den Berg, 2010; Nielsen et al., 2013); others on the share of income provided by each activity (e.g. Babulo et al., 2008; Iiyama et al., 2008; Soltani et al., 2012; Walelign, 2016; Paudel Khatiwada et al., 2017) and combined with households' assets (e.g. Alinovi et al., 2010; Diniz et al., 2013; Walelign et al., 2017; Jiao et al., 2017). It has conclusively been shown that clustering techniques such as k-means, hierarchical and latent, were the best method to profile households based on different livelihood components, and that multinomial and ordered logit modelling offer an effective way of characterising the drivers of livelihood clusters. Together these studies provide important insights into the micro-determinants of livelihood strategies, the main drivers being the availability of household labour, land ownership and access to rural infrastructures.

Meso-level studies. Much of the meso-level studies pays particular attention to the spatial component of livelihoods (Table 2.3), either by mapping assets (e.g. Erenstein et al., 2010; Jakobsen, 2013), creating livelihood indices (e.g. Singh and Hiremath, 2010; Sajjad et al., 2014; Donohue and Biggs, 2015) or characterising the determinants of poverty using the sustainable livelihoods framework (e.g. Kristjanson et al., 2005; Fang et al., 2014). Although such indices are a useful mapping tool for policy makers, they fail to break down the different livelihood components and thus to resolve the main concerns of rural poverty. Scoones (2015) has already drawn attention to the problems of quantitative indices based on livelihood capitals, as they tend to simplify the roots of rural development and thus suffer from the same drawbacks than income-based poverty analysis.

Collectively, these studies give a quantitative confirmation of the relevance of the sustainable livelihoods framework to characterise drivers of rural poverty. They also outline that households' access to capitals determine their choice of a livelihood strategy, the latter being a key driver of poverty. The evidence presented previously suggests that these determinants are spread across two levels of analysis: (i) the micro-level with determinants such as savings, ownership

Table 2.2: Micro-level livelihood studies. This table was created by reviewing and classifying the existing literature on livelihood studies. The micro-level studies are based on household surveys and they mostly aim at profiling livelihoods based on livelihood strategies.

Category and authors	Study area	Household Survey		Methods		Comments
		Source	Reduction	Clustering	Logit model	
LIVELIHOOD ASSETS						
Assets portfolio						
Orr and Mwale (2001)	Malawi	Primary	CA	K-means	-	Agricultural intensification and livelihood diversification had the most impact on improving incomes. Value of pluralist Q-squared approaches.
Ansoms and McKay (2010)	Rwanda	Secondary	PCA	K-means	-	Rural policies to adopt group-specific interventions based on livelihood profiling.
Fischer and Chhatre (2015)	India	Primary	-	Hierarchical	Multinomial	Asset profiling reveals patterns of differentiation to identify constraints and opportunities between groups.
LIVELIHOOD ACTIVITIES						
Activity portfolio						
Bhandari (2013)	Nepal	Secondary	FA	Arbitrary	Binomial	Availability of household labour, access to cultivated land and livestock ownership hinder decision to livelihood transition.
Savath et al. (2014)	India	Primary	-	Hierarchical	Multinomial	Gendered analysis allow for a more nuanced understanding of the assets that condition households' ability to adopt livelihood strategies.
LIVELIHOOD OUTCOMES						
Share of income						
Babulo et al. (2008)	Ethiopia	Primary	-	Arbitrary	Multinomial	Differential access to livelihood assets determines the choice of a household's strategy.
Iiyama et al. (2008)	Kenya	Primary	-	Arbitrary	Binomial	Proportion of income coming from various crops, livestock and non-farm activities as an effective approach for categorising livelihood strategies.
Soltani et al. (2012)	Iran	Both	FA	K-means	Multinomial	High reliance on natural resources leads to environmental degradation and poverty.
Walelign (2016)	Mozambique	Primary	PCA	Latent	Multinomial	Savings, access to credit, production implements, business cost and exposure to agricultural shock determined household's access to some livelihood strategies.
Paudel Khatiwada et al. (2017)	Nepal	Primary	PCA	Hierarchical†	Multinomial	Improving access to education, vocational training, rural credit and rural infrastructures is momentous for reducing rural poverty.
LIVELIHOOD ASSETS & ACTIVITIES						
Land and activity allocation						
Brown et al. (2006)	Kenya	Primary	-	K-means	Multinomial	Analysis shows welfare rankings among livelihood strategies, which are driven by geographic, demographic and financial determinants.
Jansen et al. (2006)	Honduras	Primary	FA	K-means	Multinomial	Per-capita income can be increased by improving road infrastructure, widening access to land and policies that reduce household size and dependency ratios.
van den Berg (2010)	Nicaragua	Primary	-	K-means	Multinomial	High welfare strategies associated with high levels of capitals. Households following low-welfare strategies trapped in poverty.
Purchased inputs and activity allocation						
Nielsen et al. (2013)	Multiple	Primary	-	Latent class	Multinomial	Access to more remunerative livelihood strategies is determined by land ownership, education and ethnic affiliation.
LIVELIHOOD ASSETS & OUTCOMES						
Assets portfolio and income-share						
Diniz et al. (2013)	Brasil	Secondary	FA	K-means	-	Environmental conditions, social organisation, market availability and agrarian reform played key roles in directing livelihood strategy choices.
Walelign et al. (2017)	Nepal	Primary	PCA	Latent	Ordered	Combining income and asset data provides a better understanding of livelihood clusters than using only income or asset data.
Jiao et al. (2017)	Cambodia	Primary	PCA	Latent	Ordered	Education, ownership of physical assets and access to infrastructures shape the choice of a livelihood strategy.
LIVELIHOOD ASSETS, ACTIVITIES & OUTCOMES						
Assets, activity portfolio and income-share						
Alinovi et al. (2010)	Kenya	Secondary	-	Hierarchical	-	Determinants of resilience are different for each livelihood cluster.

Data reduction: Cluster Analysis (CA); Principal Component Analysis (PCA); Factor Analysis (FA)

of physical equipment, ethnicity and household labour; and (ii) the meso-level with spatial determinants such as environmental conditions, access to rural infrastructures and to natural resources. However, despite the recommendations from previous poverty studies (Benson et al., 2005; Farrow et al., 2005; Okwi et al., 2007; Vincent, 2007; Kristjanson et al., 2009; Kim et al., 2016) and from few livelihood studies (Smith et al., 2001; Kristjanson et al., 2009; Angelsen et al., 2011) that have consistently shown the importance of multi-level approaches to rural

Table 2.3: Meso-level livelihood studies. This table was created by reviewing and classifying the existing literature on livelihood studies. The meso-level studies are based on a combination of multiple datasets and they mostly aim at building indices based on assets as proxies for poverty.

Category and authors	Study area		Data		Methods		Comments
	Country	Level	Source	Pre-processing	Model	Spatial	
DETERMINANTS OF LIVELIHOOD STRATEGIES AND POVERTY							
Kristjanson et al. (2005)	Kenya	Community	VA	-	Loglinear	√	Need to link qualitative and quantitative, as well as micro-, meso- and macro- levels for improved pro-poor policy and intervention targeting.
Fang et al. (2014)	China	Settlement	HH	Z-scores	Logit	√	Natural and human capitals positively correlated with farm livelihood strategies, whereas financial and social capitals are positively correlated with non-farm activities.
ASSET MAPPING							
Erenstein et al. (2010)	India	District	Multiple	PCA	Linear	√	Maps and regional contrasts of livelihood assets provide a foundation for future research and development work and reiterate the need for cross-sectoral and inter-disciplinary approaches.
Jakobsen (2013)	Bhutan	District	HH	FA	-	√	Livelihood maps provide policy-makers with a tool to quickly identify areas with limited access to certain types of assets, making the latter less able to react to climate-related risks.
LIVELIHOOD INDEX							
Hahn et al. (2009)	Mozambique	District	HH	Feature Scaling	-	-	Livelihood Vulnerability Index (LVI) to estimate climate change vulnerability. The LVI could be tested at the community level to compare communities within a district.
Singh and Hiremath (2010)	India	District	Multiple	Feature Scaling	-	√	Sustainable Livelihood Security Index (SLSI) with three component indices: Ecological Security Index, Economic Efficiency Index and Social Equity Index.
Belcher et al. (2012)	Lao	Community	VA	Qualitative	-	-	Light, low-cost tool to monitor livelihoods status and change at the village scale. Allows parties to know where and how livelihoods are improving to guide the implementation of policies.
Kumar et al. (2014)	India	District	Multiple	Feature Scaling	-	-	SLSI is a relative score-based index that provides a basis for development prioritisation to achieve sustainable development at a district-level.
Sajjad et al. (2014)	India	Block	Multiple	Feature Scaling	-	√	Increasing inequalities, improper management of resources, natural hazards and exponential population growth have created a threat to sustainable agricultural development.
Donohue and Biggs (2015)	Nepal	Eco-region	Multiple	Feature Scaling	-	√	The Multidimensional Livelihood Index (MLI) as an effective method for monitoring change at a sub-national level to facilitate more sustainable development for the future.

Data source: Village Assessment (VA); Household Survey (HH)
Pre-processing: Principal Component Analysis (PCA); Factor Analysis (FA)

poverty, there has been very few livelihood studies that have taken such a multi-level perspective, differentiating community resources from household capitals.

2.3.2 Trade-offs between livelihood capitals

Access to each livelihood asset is flexible and individuals can make trade-offs between different assets to meet their needs and mediate vulnerabilities (De Haan, 2012; Morse and McNamara, 2013). For example, Parizeau (2015) showed that informal recyclers' households in Buenos Aires (Argentina) make trade-offs between education and immediate income by bringing children to the streets. For these households, developing their human capital often requires trade-offs with other assets, in particular with their labour. Farrington et al. (1999) also argued that households flexibly combine different capitals and make trade-offs between them to achieve their livelihood strategy. For instance, a qualitative study by Moser (1998) presented an example of synergies and trade-offs between capitals for a rural woman who does not have land to cultivate. She uses her network of social relations, or social capital, to acquire a plot. Then, she decides to

construct an irrigation system for her plot, converting her household's labour (human capital) into irrigation canals (physical capital).

De Haan and Zoomer (2005) point out that these studies often do not go beyond material motives and aim: the reduction of trade-offs to the mobilisation and deployment of social and organisational resources for the pursuit of economic and environmental goals was seen as questionable by Arce (2003). Another layer of critique emerged about the flexibility of the interchanges between capitals. Capitals are bound by property relations and configurations of power, which play such a major role in inducing poverty in the first place (De Haan and Zoomer, 2005). Overall, considering the potential vulnerabilities involved in the use of livelihood assets and the need for trade-offs caused by leveraging them has to be considered to understand the sustainability of these assets (De Haan, 2012). Such an analysis, however, needs to take into account how the broader geographical, social and economic dimensions of vulnerability can impact the availability of these assets (De Haan and Zoomer, 2005).

2.3.3 Influence of livelihood capitals on livelihood strategies

The sustainable livelihood approach has been widely applied to understand the links between the activities in which households engage and the given set of capitals they have access to. Previous studies have indicated that several factors shape, constrain or influence choices of livelihood strategies (Scoones, 2009; Nielsen et al., 2013; Fang et al., 2014). These factors consist of basic material and social tangible and intangible assets that people have in their possession (Scoones, 2009) and the influence of external shocks and stressors (Barrett et al., 2001). Amongst these factors, education, physical assets and access to infrastructure were found to be the main factors enabling households to access more remunerative strategies (Jiao et al., 2017). Barrett et al. (2001) and Nielsen et al. (2013) showed that households who have highly educated members are more capable of engaging in non-farm opportunities and Diniz et al. (2013) identified that in the Brazilian Amazon, higher levels of education enabled households to engage in more remunerative strategies by combining the commercialisation of forest products with agriculture and timber exploitation.

Ownership of productive assets and the absence of financial liquidity were found to be a barrier to access to more remunerative strategies, making upward mobility difficult for poor households without capital to invest (Barrett et al., 2006). Other authors showed the influence of biodiversity protection (Salafsky and Wollenberg, 2000), soil fertility (Tittonell et al., 2010), tourism (Barrett et al., 2001), market liberalisation and agricultural intensification (Orr and Mwale, 2001) on rural livelihoods but did not characterise their associations with specific activities. Fang et al. (2014) was the only paper who presented a broad analysis of the associations between livelihood capitals and livelihood strategies. Their findings showed that natural and human capitals are positively correlated with farm livelihood strategies, while financial and social capitals are the catalyst for driving non-farm activities.

2.3.4 Livelihood profiles

The livelihood approach captures the multiple interactions between households' resources and strategies within the social and institutional environment, accentuating the ability of social actors to play an active role in shaping their own livelihoods (De Haan and Zoomer, 2005). These conceptual inputs imply that "poor" households cannot be defined as a homogeneous or rigid group, and it is thus crucial to look at the diversity hidden behind aggregate figures of poverty (Carter and May, 1999; Ansoms and McKay, 2010). Accounting for livelihood diversity is more often present in qualitative research, as most quantitative studies only test relationships between variables by using regression analysis, without characterising the heterogeneity of livelihood profiles. Some studies have attempted to account for livelihood diversity by comparing how distinct villages respond differently to the transition from subsistence farming to diversified livelihoods (e.g. Bouahom et al., 2004; Chen and Lopez-Carr, 2015) or by comparing the changes in asset portfolios in different urban settings (e.g. Moser, 1998). Although these case-study approaches enable researchers to make comparisons between settings, they have a limited external validity, which could be accounted for by identifying and comparing profiles of different groups (Ansoms and McKay, 2010).

Most papers have used clustering techniques to profile livelihoods, the main difference between them being found in the variables used to differentiate those groups (Table 2.2). For example, Fischer and Chhatre (2015) used several variables representing assets to generate four livelihood profiles in the Thaltukhod Valley in India: (i) lack of asset; (ii) investments in stall-fed cows; (iii) labor and education; and (iv) large landholdings. They show that different asset-livelihood combinations imply different bundles of risks, with different vulnerabilities to loss and injury and different constraints and opportunities. As a consequence, each livelihood profile, characterised by a specific combination of assets, can only access particular strategies, as demonstrated by Ansoms and McKay (2010). This combination of asset bundles with livelihood strategies enabled the researchers to highlight distinct livelihood profiles in rural Rwanda, from well-off rural entrepreneurs to resource-poor subsistence farmers in fertile regions. These studies outline that rural poverty cannot be characterised by aggregated wellbeing indicators, which define poor households as a homogeneous group. Households have access to bundles of resources, which will influence their choice of a livelihood strategy. Identifying livelihood profiles is a useful tool to characterise the causes and conditions that shape household vulnerability in different contexts.

2.3.5 Dynamics of rural livelihoods

People can be poor at any point in time because they possess too few assets to generate sufficient income, or because of limitations on their ability to use the assets they possess (Carter and May, 2001). However, changes that happen can create new opportunities for households. For example, households can accumulate assets through time or remove barriers to their access to specific assets, enabling them to choose activities that could temporarily or permanently reduce their

poverty (Barrett et al., 2001; Carter and May, 2001; Ellis, 1998, 2000b). Similarly, negative shocks might occur over time, driving some households further into poverty. Upward mobility can be observed, for example if households manage to adopt a more remunerative livelihood strategy. Likewise, downward mobility can be observed when households transit to a less remunerative livelihood strategy (Carter and May, 2001). However, upward or downward mobility are not necessarily observed and some households might stay poor (or non-poor) by keeping the same livelihood strategy or shifting to an equally remunerative livelihood strategy. Households' decision of changing their livelihood strategy is affected by their assets, the outcomes of previous livelihood strategies, by their investments and savings, and by the wider environmental and socio-economical context (Figure 2.4). In general, three main dynamics are observed in a rural context (Giesbert and Schindler, 2012; de Sherbinin et al., 2008): agricultural intensification or extensification, diversification of income-generating activities, or migration to look for alternative livelihood opportunities.

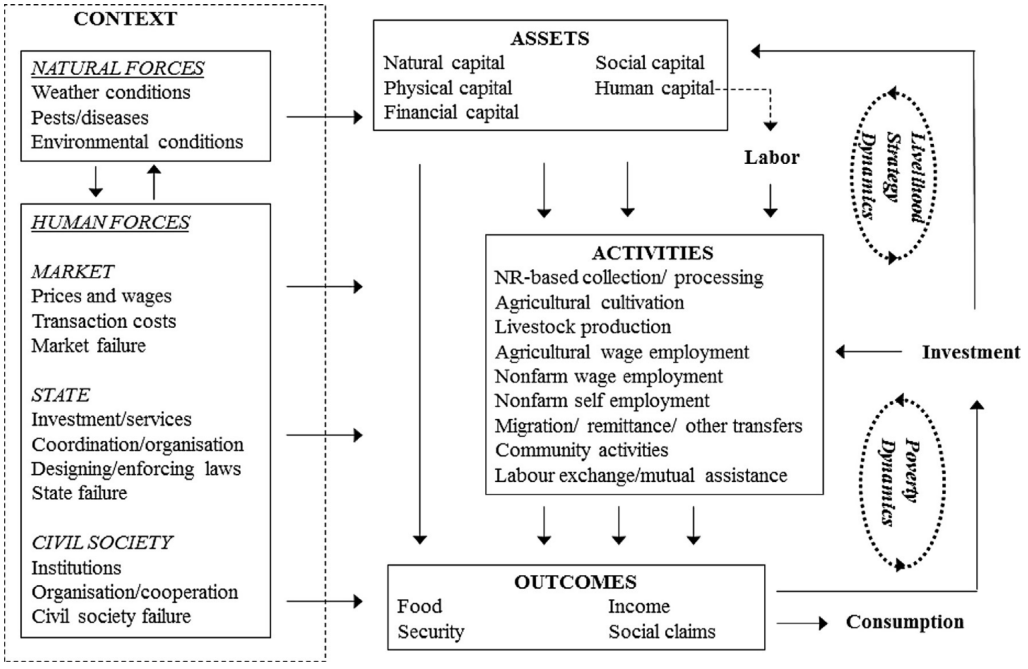


Figure 2.4: Dynamic household livelihood strategy framework. This framework (Jiao et al., 2017) is based on the household livelihood strategy framework (Nielsen et al., 2013) originally adapted from Winters et al. (2001).

Few studies have analysed dynamic household-level strategy choices and their determinants, either qualitatively (e.g. Wiggins, 2000; Mushongah and Scoones, 2012) or quantitatively (e.g. van den Berg, 2010; Bhandari, 2013; Walelign et al., 2017; Jiao et al., 2017). Together these studies show that most households change their livelihood strategies over time in response to evolving pressures, incentives and opportunities, except the poorest who lack livelihood opportunities. Moving out of poverty requires an intermediate step during which households accumulate assets, either through farming, petty trading and seasonal migratory labour. According to Jiao et al. (2017), access to this step leading to more remunerative strategies is principally shaped by the level of education of the household's members (human capital), the ownership of physical assets (physical capital) and access to infrastructures at the community level (community

physical capital, as argued in this thesis). On the other hand, Bhandari (2013) argues that the availability of household labor (human capital), access to cultivated land (natural capital) and livestock ownership (financial capital) are the main factors influencing livelihood change. He also demonstrates that the proportion of non-farm households in the community has a positive influence on farm-exit. Based on the work of Dorward et al. (2001) about the categorisation of livelihood transitions, Mushongah and Scoones (2012) suggest that livelihood transition processes lead to the formation of class and to agrarian change. They argue that "stepping up" and "stepping out" categories relate to the process of accumulation, principally linked to off-farm activities. On the contrary, "hanging in" and "dropping out" include a wider group of "footloose labour". Overall, these studies outline that, in agrarian societies, the context is a key determinant of livelihood transition. Mushongah and Scoones (2012) argue that extended periods of drought give rise to very difficult livelihood conditions, especially when combined with political crisis and economic collapse. They also demonstrate that the availability of off-farm employment coincides with patterns of good or bad rainfall or economic boom, which has a key influence on people's livelihood trajectories.

2.4 Political economy of rural livelihoods in India

India is independent since 1947 and despite being currently one of the fastest-growing economy in the world, poverty and inequalities continue to bedevil its economy. This paradox of economic success and deprivation makes the study of Indian political economy complex but also essential to every economic and social analysis of India, especially the understanding of the intersections between social integration, politics and economics (Sinha, 2016). An example of such a paradox can be illustrated by analysing the agrarian political economy of India, which is presented in the first subsection.

The underlying processes of the origins of social interactions must be distinguished from the logic of the structural processes influencing livelihoods. Thus, the review of the political economy of livelihoods is organised according to the following structure. The first section focuses on the power relationships of caste, class and gender and how they interact with labour. The following sections presents an analysis of the agrarian political economy of India, including a political economy of land and a regional political economy. The last section presents a policy and institution analysis focused on the state of Odisha.

2.4.1 Agrarian political economy of India

At the beginning of the Nehru-Mahalanobis years (1947-1964), only 15% of the cultivated land was irrigated, resulting in a high dependency on the monsoons for agricultural production and thus a low agricultural productivity (Nagaraj, 2018). To increase agricultural production and to break the existing agrarian structure, which was highly unequal in landownership enabling landlords to extract usurious interest from the mass of peasantry, the government implemented

an institutional approach, consisting of three elements (Posani, 2009): (i) implementation of land reforms to provide incentives to tillers to produce more; (ii) setting-up farm and service co-operatives to bring in economies of scale and better access to inputs; and (iii) reform local self-government to enable the poor to ensure that the reforms and co-operatives were not captured by the landed oligarchy in complicity with local bureaucracy (Varshney, 1998). However, the increase in production that was observed until 1960 was due to expansion of cultivated land and not an increase of agricultural productivity. The failure of these reforms has been identified to be linked to its implementation (at the State level), where power relationships between rich landlords and bureaucrats managed to prevent the reforms to happen. As a consequence, during that time, no progress was made on land reforms, as panchayats became another source through which the local "influentials" yielded political power (Varshney, 1998).

With the death of Nehru, the new Ministry for Food and Agriculture (Chidambaram Subramaniam) initiated a shift in India's agricultural policy, changing from an institutional approach to a technocratic model aiming at "betting on the strong", with three components: (i) economic through price incentives to farmers to increase production; (ii) technological through investments in technology to increase productivity (such as high yielding varieties); and (iii) organisational through the creation of new institutions to support the first two components. This policy shift led to an increase in fiscal demands, as the high yielding variety (HYV) seeds required controlled water and chemical fertilisers (Sidhu and Gill, 2006; Sinha, 2016). To incentivise farmers to adopt the HYV package, the government provided subsidies on inputs and developed irrigation infrastructures across the country. However, the amount of incentives received was disparate between and within states, remote and underdeveloped regions being left behind of these investments in agricultural infrastructures.

The rich peasantry, who had gained political power thanks to the institutional strategy, also benefited from the technocratic strategy, which focus was to bring the newest agricultural technologies where rich peasants were powerful. As a consequence of these reforms, the higher classes of Indian peasantry locked themselves into a upward spiral of wealth and power, letting the lower classes of peasantry underdeveloped (Corbridge and Harriss, 2013). Today's agrarian system still reflects these dynamics, with a skewed pattern of land ownership that reflects the lack of earnest land reforms. Small farmers are becoming more marginalised and are are forced into sharecropping and in renting land. The increasing costs and inadequate returns from production has resulted in declining standards for small and marginal farmers (Lerche, 2011).

Following the liberalisation in 1991, the public sector gradually withdrew its support from the sector of rural development, especially by reducing its investments in rural infrastructure, irrigation and input subsidies, which led to an increase in the overall cost of cultivation for farmers (Suri, 2006). The waning of state-support led to the collapse of agricultural pubic institutions that were supporting farmers, which functions were taken up by the private sector. Unregulated private dealers of inputs also became the main provider of extension services, luring farmers into buying low-quality expensive packages (Reddy and Mishra, 2010). The lack of maintenance of irrigation infrastructures led to an increase of private investments in using ground-water, overexploiting this resource and increasing farmers' expenses because of the

increasing cost of installation and maintenance of electric motors to draw water from the wells and the electricity to run them. The surge in cheap agricultural imports resulting from the trade liberalisation of agricultural commodities led to a decrease of farmers' output price. The majority of smallholder farmers, who cannot compete on the world market and who need to sell directly after harvest due to loan pressure, have to sell at low prices, thus compromising their income.

Overall, the liberalisation of the agricultural economy combined with the collapse of public agricultural support and with the recurrence of crop failures due to climate shocks have pushed farmers into long-term debt traps (Lerche, 2011). Due to the high input costs of HYV packages, farmers need to look for external sources of credit from formal financial institutions (commercial and co-operative banks). However, the privatisation of these institutions after the liberalisation led to a decrease of credit availability for farmers, tenant cultivators being denied access to formal credits (Suri, 2006). The inability for smallholder farmers to access formal credit force them to rely on "informal sources", usually in the form of inputs (seeds, fertilisers, etc.) issued against the future agricultural output, whose price is fixed by the moneylender with usurious interest rates (Suri, 2006), pushing farmers into a long-term indebtedness.

2.4.2 Caste, class, gender and labour in rural India

Following the structural reforms presented earlier, the State now plays a marginal role in contemporary rural India. Households' decisions are made in a risky environment without formal social protection mechanisms. In particular, climate shocks might lead to important variations of income year-to-year, the vast majority of the population living in rural areas and depending on agriculture for their livelihoods (Nagaraj, 2018). It is under the light of such a context that it seems necessary to understand the caste system in contemporary India, as a "traditional" institution in a country that is getting modernised. The objective of this section is not to give a historical or sociological perspective on the systems of caste, class and gender, but rather to present their consequences in terms of power relationships, labour, poverty and politics.

The caste system. The caste system in India divides society in four distinct categories, also called *varnas* (one of two translations of "caste"), which relate to endogamous groups that are linked to traditional activities. These groups follow a hierarchy based on their "purity" and type of occupation (Dumont and Pocock, 1957): the Brahmins (priests, scholars and teachers); the Kshatriyas (rulers, warriors and administrators); the Vaishyas (agriculturalists and merchants); and the Shudras (labourers and service providers). Communities which belong to one of the three first varnas are the highest three castes of Hindu society, known as the twice-born, while under the Shudras fall under the lowest castes. Finally, there is another group that do not belong to any varna, which gathers Dalits (or untouchables) and scheduled tribes. This last group, also called *avarna*, is at the bottom of the caste system because of their historic hereditary occupations being considered as "impure" (working with leather, garbage collection, etc.), as defined by Srinivasulu:

> "The concept of Dalit does not refer to any single caste or group of castes; it is a relational category. Its reference point is the caste specific relationship of dominance and subordination in Indian society. Thus the concept of dalit may be defined as a community of oppressed castes with specific experience of being treated as untouchables and being humiliated through the conscious denial of self-respect and honour by caste Hindus"
>
> Srinivasulu (2002)

Each one of these five groups is composed of *jatis* (second translation of "caste"), which are hierarchical endogamous groups that constitute the reference of everyday life in rural India. The membership of an individual to one of this category is determined by birth: a child belongs to the same caste as their parents (Ghurye, 1969).

The purity-impurity ranking principle between castes commands specific behaviour norms between different hierarchical levels. For example, Brahmins cannot share water or their meal with a lower caste member, while physical contact with "untouchables" (even with their shadow) is considered as "polluting". Similarly, marriage with someone outside one's jati is extremely rare and can lead to one's excommunication from the caste, especially if the marriage is with someone from a lower caste (Ghurye, 1969). However, for a woman to marry a member from a superior caste can be highly sought as the woman can then "take" her husband's caste. Such an orthodoxy also applies to activities: a member from a high caste will not be able to engage in activities seen as "polluting", while a low caste member will be prevented from engaging in an activity that would differ from their caste's traditional occupation (it would "pollute" higher caste engaging in the same activity). Table 2.4 shows the different varnas and the share of the population that belongs to each category. The share of the population belonging to low castes (other backward castes) or untouchable (scheduled castes) represent more than the majority of the total population in 2009-2010 (55%).

Table 2.4: Caste system and share of the Indian population. The figures are a rough estimate evaluated from surveys and not from the national census as there is no data about Other Backward Castes (source: NSS 66).

Varna	Share	Official category	Positive discrimination
Brahmin *Kshatriya* *Vaysha*	22%	None	No
Shudra	36.4%	Other backward classes	Since 1991
Dalit (untouchables)	19.4%	Scheduled castes	Since independence
Muslims	7.5% 6.0%	None Other backward classes	No Since 1991
Adivasi (autochthonous)	8.7%	Scheduled tribes	Since independence

Social policies. As a response to this system that locks individuals within a caste, and which social sanction mechanisms impose to follow behaviour norms that prevents upscale social mobility, the Indian government chose to put in place positive discrimination policies for Dalits (scheduled castes) (Chandra, 2004). By providing them reserved positions in administrative institutions, universities and political assemblies, such programmes allowed the caste system to be reworked from a largely vertical hierarchy of "pure" and "impure" castes to a more horizontally organised system of competing ethnic groups (Chandra, 2004). Although special laws such as the Protection of Civil Rights Act (1955) and the Prevention of Atrocities Act (1989) were developed in order to punish caste discrimination, scheduled communities continue to be locked out of local and national circuits of power and prosperity, leading to a limited social mobility. It seems important to emphasise that castes are not a homogenous category and that internal differences within jatis can lead to class opposition between endogamous low-castes, which can be hierarchical or not. A specific caste can become "dominant" when the number of its members is higher than other castes and when it posses a leading economic and political power. A numerous and powerful caste is more likely to become dominant if its position in the local caste hierarchy is not too low (Oommen, 1970). The number criteria is only relevant at a local or regional scale; at the State level dominant castes are usually in minority. In the village context, economic power and "dominance" is related to land ownership (Srinivas, 1959). In Orissa, upper castes have been economically dominant but also in society, through land ownership and education, with Brahman power further entrenched in politics (Lele, 1990).

Caste, class and labour. Caste is not only a sociological artefact but also a political association and an economic category, as economic inequality seems to be related to the influence of inherited social-economic stratification (Sinha, 2016). For example, the socioeconomic hierarchy conceptualised by class is linked to ownership and income and plays a significant dimension in the caste system (Lele, 1990). Actually, although the caste system is no longer connected to the type of activities conducted by its members, high status employment is dominated by upper caste, while physical labour and low status jobs are mostly performed by lower caste or dalit (Figure 2.5). As a consequence, income disparity is highly associated with the caste system (Levien, 2015). 1

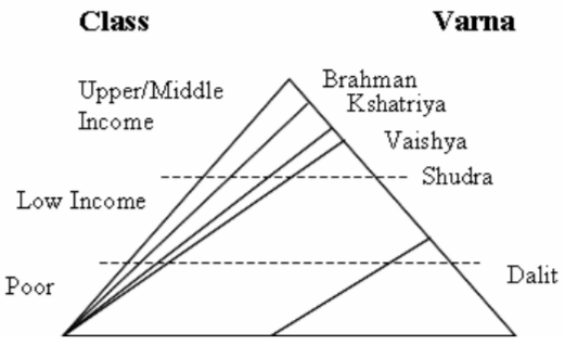


Figure 2.5: Interconnection between caste and class. Although upper castes (Brahmins, Kshatriyas, Vaishyas) dominate the upper and middle class, a minority falls under the class "poor". Shudra and dalit mainly belong to the lowest class (source: Olsson 2009)

Gender and labour. Gender is another type of social structure that shapes access to labour through the gender division of work. In the household, women are considered responsible for household work, such as cooking, cleaning and caring activities, while men, on the other hand, have the social position of "breadwinners" and heads of households (Kelkar and Kumar Jha, 2016). Moreover, in terms of power relationships, men exercise authority over women and children. This division observed at the household level also extends to the labour market and to the governance of the means of production. As a consequence, livelihood outcomes are gendered as a result of gender inequalities in the control of assets, the segmentation of agricultural labour and the burden of reproductive or care activities on women (Naidu and Ossome, 2016). Women remain in the lowest classes of the system as they mainly engage in low-paid work, their work mostly being regarded as unskilled (Kelkar and Kumar Jha, 2016). These studies show that women's activities are defined within customary laws, although recent literature suggests that adivasi women might enjoy equal status with their male counterparts (Prasad, 2016), which sheds new light on the division of labour. According to Kelkar and Kumar Jha (2016), it is at the community level that the division of labour and the functions performed by women is structured. However, Prasad (2016) argues that the labour market is only structured by macro-economic processes of dispossession, which shaped women's access to livelihood opportunities. As a conclusion, gender and caste are overarching mediators in the capital–labour relationship and are linked to the class-based structures of accumulation.

2.4.3 Rural tenancy in India

Access to land is one of the mains asset for rural households and communities to pursue their livelihood objectives and to eradicate poverty. As a consequence, land reforms have been a central element of Indian policies aiming at the reduction of rural poverty. This section reviews the challenges of land access in rural India, with a focus in the interests and capabilities of the rural poor.

Tenancy reforms. Before Independence, tenancy was cast in the social and economic hierarchy and was described as exploitative (Appu, 1997). Landlords from upper castes were using their positions of social and economic privilege to exploit rural poor, who did not have access to land nor to economic opportunities and smallholder tenants who had little bargaining power. According to Besley et al. (2016), two categories of tenants can be highlighted: (i) occupancy tenants who had rights on land and security of tenure and were usually from middle or lower castes; and (ii) tenants at will, who lacked tenure security and could be evicted at the landlord's will, usually from the lowest castes and tribal households. Following Independence, Indian economists stated that markets would not be able to redistribute land to the poor and that only bureaucratic action could accomplish this effectively (Deininger, 2007). According to them, the redistribution of land to the marginalised was necessary in order to increase agricultural productivity and to uplift the rural poor thanks to a greater equality of opportunities. As a consequence, most Indian states adopted legislations in order to transfer land to the tiller and

to increase tenants tenure security, which were of three types (Appu, 1997): (i) abolition of intermediary tenures; (ii) redistribution of land via land ceilings; and (iii) the regulation of tenancy. The extent and nature of the legislations varied from state to state. In particular, the state of Odisha's legislation prohibited agricultural tenancies, except for certain categories of people, such as widows, minors and marginal holders. According to the 48th National Sample Survey, banning and restricting tenancy led to a substantial decrease of the agricultural area under tenancy to 8.3% of the total operated area in 1992. However, as pointed out by Appu (1997), the implementation of these legislations has been mostly counterproductive, leading to the eviction of tenants or to their rotation among landlord plots to prevent them from acquiring rights. The author also concludes that tenants were evicted in more than 30% of the agricultural area, while the positive effects of tenants acquiring ownership or owner-like rights has only be seen in 4% of the operated area. Overall, the literature points out that controlling tenancy has restricted livelihood opportunities for the rural poor: (i) access to land for poor has decreased due to the reduced supply of land available to rent; (ii) land is under-utilised due to landowners' fear to lose their land if they rent it out; and (iii) there is a lack of legal protection for tenants, forcing farmers to operate in informal tenancies (Besley et al., 2016). For example, the Tenth Five Year Plan (2002-2007) recognised that "the prohibition of tenancy has not really ended the practice. On the other hand, it has resulted in agricultural practices that are not conducive to increased production. This, in turn, also depresses employment opportunities for the landless agricultural labourers".

Tenancy markets. The current legislation on the Indian land market force landowners to select trusted tenants who would not reveal the nature of their relationship nor assert their rights. However, an alternative view advocating for tenancy regulation has now emerged in the present policy dialogue. This paradigm shift is based on the growing economic literature that has shown that land rental markets can increase land access for the poor by improving the bargaining position of tenants (Lastarria-Cornhiel and Melmed-Sanjak, 1999). According to Sadoulet et al. (2014), liberalising the land market could enhance transfers of land from land-rich to land-poor households. The authors argue that land rental is the best alternative to land ownership, as it can also reduce the vulnerability of poor households by stabilising the labour market and developing opportunities, such as migration or livelihood specialisation. For example, households that have the skills to engage in non-farm activities would benefit from being able to rent out their land for others to cultivate (Hanstad et al., 2004).

Access to land. Social and cultural norms in India limit women and lowest caste to exercise their right to own and manage land and productive assets. Landowners only rent land to farmers that are perceived as less risky, such as large farmers (who qualify for tenancy protections) or farmers from the same socio-economic class and caste. Such a structure of land relations work as a barrier against women, scheduled castes and scheduled tribes' economic agency and legal entitlements by preventing them to get access to land (Mohanakumar, 2014; Kelkar and Kumar Jha, 2016).

2.4.4 Policy and institutional analysis

The purpose of this section is to review the main policies, institutions and processes that have an influence on one or several components of livelihood systems. A review of the grey literature was used to highlight the policies with the most important influence on the components of livelihood systems. This part of the political economy analysis only focuses on the State of Odisha.

Providing employment. The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is a labour law implemented by the Central Government of India that aims to guarantee the "right to work" by providing employment to the rural poor of marginalised communities such as nomadic communities, scheduled and unscheduled tribes, BPL families, women-headed families and the families headed by disabled persons and those who have got their dwelling through the Indira Awas Yojana scheme. The MGNREGA covers all the districts of India since April 1, 2008, and guarantees 100 days of work each financial year to every household whose adult members volunteer to do unskilled manual work, at a fixed wage (174 Rs/day in 2015 for the state of Odisha) and within five kilometres of the applicant's residence. Wages are paid through bank transfer within fifteen days, however, issues of bank accessibility for household and money availability from the government leads to a payment delay of 2 months usually (Economic Survey 2014-15, 2015). One of the main critics of the scheme, however, is that wages are lower (174 Rs/day) than the labour market (300 Rs/day), so households prefer to find daily wage labour themselves even if it is not guaranteed rather than asking for MGNREGA work. The type of work provided by the programme aims to create durable assets and improve community infrastructures through labour-intensive tasks such as the construction of roads, dams, canals, ponds or other water-harvesting infrastructures to mitigate drought. It is not yet clear whether the scheme enables households to move out from distress migration, thus if it leads to a shift of livelihood strategies (Panchayati Raj Department, 2015b). The MGNREGA has an influence on two components of livelihood systems: (i) on community capitals by leading to the creation of durable community amenities and infrastructures; and (ii) on livelihood activities by ensuring households to have access to 100 days of wage labour.

Creating employment opportunities. The National Rural Livelihood Mission (NRLM) is another flagship livelihood programme launched by the Central Government of India, which aims at reducing poverty through self-employment and wage employment opportunities. The underlying approach is that creating employment opportunities (self-employment and wage employment) enables the rural poor to become productive agents (Government of India, 1999). The NRLM's approach encompasses four different tasks: (i) mobilising all rural households into effective Self-Help Groups (SHGs) and their federation; (ii) improving access to credit and to rural services for the rural poor; (iii) building capacities and skills of the rural poor; and (iv) improving support services. Self-Help Groups are village-based financial intermediary committees composed of a dozen of women, functioning either as an investment plan for raising capital

(similar to a tontine) or as a group to develop income-generating activities (Pattenden, 2010). However, according to Datta (2015) the performance record of the programme is quite low: in March 2014 there were 10,434 SHGs, of which 473 only were linked to bank credit. To summarise, the NRLM programme plays a role in two different components. Firstly, it strengthens social capital at both the community and household levels by promoting SHGs. Secondly, it provides new income-generating opportunities to households and especially to the most vulnerable ones (SHGs are composed by women), which play a crucial role in adaptation mechanisms.

Improving rural housing. The Indira Aawas Yojana (IAY) scheme that was later continued with the Biju Pucca Ghar Yojana (BPGY) programme is a rural housing scheme initially run by the central government (for IAY) and then by the Odisha Government (for BPGY) (Government of Odisha, 2011). The aim of this scheme is to convert all mud houses (*kutcha*) to concrete houses (*pucca*). The schemes define *pucca* house by the following: "it should be able to withstand normal wear and tear due to usage and natural forces including climatic conditions" (Ministry of Rural Development, 2011; Panchayati Raj Department, 2015a). In other terms, *pucca* houses have their foundations, walls and roof made of a permanent material such as stones, bricks, or cement concrete and should stand for at least 30 years. As a conclusion, these two schemes play a role in livelihood capitals and outcomes, by improving the condition of housing in rural areas.

Developing commercial agriculture. There are many schemes falling under the Directorate of Agriculture & Food Production, either initiated by the Government of Odisha or by the Central Government (Directorate of Agriculture & Food production, 2015). One of the flagship programmes is the "Input Subsidy" scheme that aims at distributing seeds at subsidised rates. As a consequence, the choice of the seeds to subsidise shows the paradigm under which the Agricultural Department falls and the direction it wants agriculture to develop. There is a strong governmental emphasis to subside hybrid paddy varieties that are more sensitive to fertilisers than local varieties, which allow farmers to increase their yield (if they are able to purchase fertilisers). However, it has been reported that new varieties are not as resistant to climate variability than traditional seeds: during the 2011 floods in Jagatsinghpur, local seeds resisted while new seeds rotted. To increase the availability of fertilisers, the Directorate of Agriculture & Food production (2015) also put in place a new scheme that allows everyone to sell fertilisers (fertiliser reseller) and also developed storage facilities. As a consequence, the quantity of fertilisers used by farmers has considerably increased: from 48kg/acre (2010) to 63kg/acre (2015) Duncan et al. (2017). Another flagship scheme from the department of agriculture is to popularise agricultural implements and equipment (following on from the "Green Revolution") by stimulating the purchase of motorised agricultural equipment such as tractors or motor-pumps for irrigation through interest-free loans. Those schemes enable rural households to increase their physical capital, however, the sustainability of such incentives is yet to be assessed.

Improving food security. The National Food Security Mission (NFSM) following on from the National Food Security Bill (Ministry of Consumer Affairs, Food, and Public Distribution, 2011) and the National Food Security Act (Ministry of Agriculture of India, 2013) is a scheme that aims at providing subsidised food grains to India's poor households through a public distribution system (five kilograms per person per month of rice, wheat and millet at a subsidised price) and to increase production and productivity of wheat, rice and pulses on a sustainable basis so as to secure the food production of the country. At the agricultural level, there are three main axes of work: (i) restoring soil fertility and productivity at the individual farm level; (ii) creation of employment opportunities and enhancing farm level economy; and (iii) promotion and extension of improved technologies. As a conclusion, the public distribution system plays an important role in livelihood outcomes, especially for agricultural and wage-labourers who cannot produce enough food to be food secure.

2.5 Rural livelihoods in the Mahanadi Delta

The Mahanadi Deltaic region constitutes 25.8% of the State area and benefits from fertile soils that support extensive paddy cultivation (Nathan et al., 2008). The narrow margins of the coast are highly valuable for agriculture thanks to the fertility of their alluvium soils. As a consequence, agriculture is well-developed with more than 60% of the population relying on agriculture as their main economic activity (Samal et al., 2006; Sahu and Nayak, 2007). Rainfed rice is the major cultivated crop, which is grown mainly during the *kharif* season and accounts for 92% of the total production (Samal and Pandey, 2005).

2.5.1 Poverty and types of rural communities

According to Nathan et al. (2008), levels of poverty in the delta have been divided by two between 1983 and 2004 (from a poverty ratio of 57.9% to 27.4%), and are lower than in the other parts of Odisha (ratio of 46.9% at the state level in 2004). However, these relatively good figures tend to hide huge disparities between social groups. Scheduled Tribes (ST) and Scheduled Castes (SC) designations are the basis of a governmental national program of entitlement distribution for disadvantaged social groups. Odisha has a high proportion of ST and SC and the poverty ratio among those groups is much higher: 67.7% for ST (more than twice the average ratio); 32% for SC and 24.4% for the Other Backward Classes (OBC) (Registrar General and Census Commissioner, 2011). The remaining social groups (non-disadvantaged) have a lower poverty ratio: only 19% of the population is considered as poor within this group.

Two types of rural communities can be distinguished in the Mahanadi Delta: fishing communities and agricultural communities (Venkatesh, 2006; Iwasaki et al., 2009; Savath et al., 2014a,b). According to Venkatesh (2006), fishing communities are only present in four of the five districts of the study area: Bhadrak (where they represent 3.2% of the rural population), Kendrapara (3.2%), Jagatsinghpur (3.6%) and Puri (3.0%). They are distributed along the coastline or along

Chilika Lake, which is the largest brackish-water lake in Asia and the leading centre for fishing activities in Odisha (nearly 132 villages and 125,000 fishers depend on Chilika Lake for their livelihoods) (Iwasaki et al., 2009). Their livelihoods depend on the fishing industry, with different groups spread along the marketing channel. According to Tietze (1985), five functions can be highlighted in the fishing economy of the Mahanadi Delta: production (e.g. catching fish), processing, marketing, finance/credit, and manufacture of the means of production (e.g. boatbuilding, engine repair and net making). Most of the men from poor households work as producers in non-mechanised boats or wooden catamarans, while women are confined to post-harvest and shore-based activities. Fishers' livelihoods have faced many natural hazards during the last decades, such as recurrent flooding, cyclones and declining fish. Because of the subsequent decline in income, several fishers have accumulated debts and eventually have migrated and resettled in urban areas as manual labourers (Venkatesh, 2006). As a conclusion, the key issues and threats for these communities' livelihoods are their dependence on common-pool resources with contested use rights, their low ownership of assets and erratic incomes that lead to distress sales and then migration (Tietze, 1985; Venkatesh, 2006; Iwasaki et al., 2009).

Recent research has suggested that more than 30% of rural households are landless labour households who are completely dependent on wage employment for their livelihoods (Mahapatra, 2007; Savath et al., 2014a). However, the majority of rural households are composed by marginal and small farmers who have very low income from their land; they represent 60% of the total number of rural households in Odisha (Mahapatra, 2007; Savath et al., 2014b). In both cases (which accounts for 90% of the rural population), they complement or totally earn their income with outside labour and wage employment. One of the hypotheses ventured by Mahapatra (2007) is that livelihood strategies are dependent on agricultural productivity; the latter being low in Odisha because of the recurrence of climate stresses that lead to crop failure.

2.5.2 Livelihood activities

The most common livelihood activities in the delta are agricultural labour (for almost half of the households), cultivation of rice and rearing of cows and draft animals (Table 2.5). By aggregating these different activities, Savath et al. (2014a) have identified four main livelihood strategies in the coastal plains region of Odisha: (i) agricultural wage labourer; (ii) off-farm wage labourer; (iii) wage labourer with a farm; and (iv) farm and self-employment.

"Agricultural wage labourers" have their main activity based on agricultural work on other farmers' lands and they are not engaged in their own cultivation nor livestock rearing. "Off-farm wage labourers" rely on wage labour that is not directly related to agriculture (e.g. factory, construction) and they are not engaged in their own cultivation nor livestock rearing. "Wage labourers with a farm" have the particularity of spreading their activities between cultivation or livestock rearing and wage labour. The last category highlighted by Savath et al. (2014a) is "farm and self-employment" and gathers households that conduct the following activities: cultivation, livestock rearing and other income-generating activities.

Table 2.5: Livelihood activities in the Mahanadi Delta. The most common livelihood activity are daily-wage labour (agricultural and non-agricultural) and cultivation (rice and fruits). Adapted from Savath et al. (2014a).

Livelihood activity	Proportion of HH
CULTIVATION	
Rice	34.5 %
Fruits (e.g. mango, banana, coconut, papaya)	26.0 %
Vegetables (e.g. green leafy vegetables, pumpkin, beans)	8.2 %
LIVESTOCK REARING	
Cows	20.9 %
Draft animals (horses, oxen)	18.2 %
Small animals (pigs, goats, sheep)	12.7 %
Poultry (ducks, pigeons, chickens)	9.9 %
EMPLOYMENT	
Agricultural labor	49.7 %
Non-agricultural wage labor	32.0 %
Self-employed	17.2 %

2.5.3 Challenges and main trends

In the state of Odisha, 64.14% of the overall agricultural area consists of rice, while pulses and oilseed respectively account for 13.14% and 11.29% of the total agricultural area. The other crops that are grown in the region are groundnut (6.68%), sugarcane (2.09%), maize (1.47%), ragi (0.74%) and cotton (0.45%). Even if the dynamic of poverty seems to be on the decrease (Hatlebakk, 2014), the poverty ratio in Odisha is still amongst the highest in India, notably because of the very unstable agricultural and fishing production in the state (Nathan et al., 2008). Returns to cultivation are low with an income of around 5,000 Rs. per ha, which translates to an average of 4,000 Rs. per household (Patra, 2014). Moreover, Odisha is the fourth most unstable state in India for agricultural production, due to the prevalence of weather stresses, especially erratic rainfall that leads to submergence, floods, moisture stresses and droughts (Mohan, 2010). According to Panda (2016), 40% of the variance in the production of *kharif* rice can be explained by rainfall anomalies, a decrease in rainfall leading to a lower production of rice. High disparities can be highlighted between districts: the share of irrigated area is greater in the district of Jagatsinghpur, which also shows a greater agricultural development (Ghosh and Verma, 2012). On the contrary, the districts of Puri and Kendrapara have very low yields of rice, despite a great share of irrigated area, especially for Puri. One important fact to notice is that the district of Kendrapara is not well-connected, with less than 30% of paved roads, which brings down its level of food access (Nathan et al., 2008).

As was mentioned previously, population growth and the process of land inheritance have led to an increase in land pressure that is likely to catalyse environmental degradation (Hatlebakk, 2014). Figure 2.6 shows the dynamics of farm holdings since 1995, and the increase in the number of individual farm holdings (+18%) goes along with a decrease of their area (-6%), leading to a sharp decline in the average size of farm holdings (-20%, from an average to 1.29 ha/holding in 1995 to 1.03 ha/holding in 2010). This trend should be considered with reference to the dynamics of livelihood activities: although the engagement in agricultural

activities (cultivation and agricultural labour) has slightly increased (+4%), many people have left cultivation (-14%), which went hand in hand with an increase in the number of agricultural labourers (+20%) (Registrar General and Census Commissioner, 2011). One of the hypotheses that can be formulated to explain these trends is that many people have had to switch their activities from cultivation to agricultural labour to cope with external shocks, especially with agricultural stresses (Duncan et al., 2017).

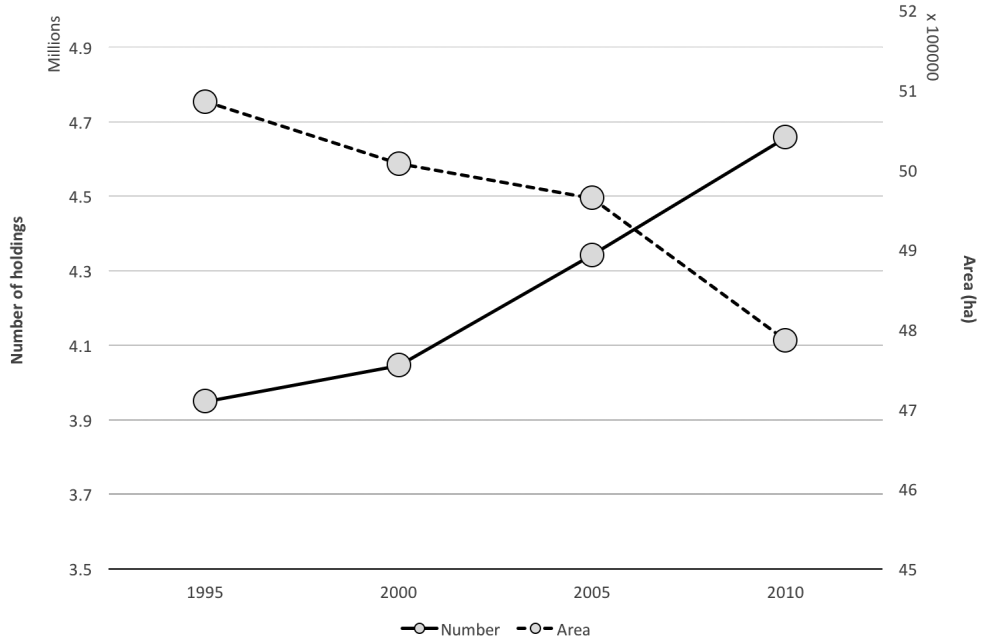


Figure 2.6: Evolution of farm holdings in Odisha between 1995 and 2010. Based on data from the Agricultural Census of India.

CHAPTER 3 Local perceptions of livelihood systems

This chapter examines the local perceptions of livelihood systems in the Mahanadi Delta, identifying factors that are perceived by rural households as having an influence on their livelihood opportunities and understanding the perceived importance of community assets for rural households' livelihoods. Controlling for the role of social relations of class, caste and gender, villagers valued community capitals and considered them as one of the key factors influencing their livelihood opportunities. Natural and physical household capitals are perceived as drivers of on-farm activities, especially access to agricultural land. On the other hand, human, financial and social household capitals are seen as leading to engage in off-farm activities, especially great workforce availability and low dependency ratio, access to financial services and being involved in migration or employment networks. The chapter shows that access to both physical and natural community capitals enables households intensify their current agricultural practices for commercial purposes, while households are more likely to diversify their production in communities with a low physical community capital. In contrast, it is likely that households reorientate their activity portfolio towards off-farm activities within communities with a low natural community capital but a strong physical community capital. However, villagers from these communities keep agricultural activities for subsistence, whereas in communities benefiting from low physical and natural community capitals, households might disengage totally from agriculture and out-migrate. The chapter also shows that climatic stressors leading to crop failure are perceived by villagers as one of the most important external factor influencing their livelihoods.

Results from this chapter were presented at the ESRC conference "Climate Change: Society, Governance & Economics" in Reading (UK), June 2016 and at the Tropmet conference "Climate Change and Coastal Vulnerability" in Bhubaneswar (India), December 2016.

3.1 Introduction

Recent research has suggested that more than 30% of rural households are landless labour households who are completely dependent on wage employment for their livelihoods (Mahapatra, 2007; Savath et al., 2014a). However, the majority of rural households are composed by marginal and small farmers who have very low income from their land; they represent 60% of the total number of rural households in Odisha (Duncan et al., 2017). Looking at the activities that households conduct (Table 2.5), the most common agricultural activities are cultivation of rice and rearing of cows and draft animals. When it comes to employment, as shown in the table, almost half of the households are engaged in agricultural wage labor. By aggregating these different activities, Savath et al. (2014a) have identified four main livelihood strategies in the coastal plains region of Odisha: (i) agricultural wage labourer; (ii) off-farm wage labourer; (iii) wage labourer with a farm; and (iv) farm and self-employment. Agricultural wage labourers are not engaged in their own cultivation nor livestock rearing and their main activity is based on agricultural work on other farmers' lands. Similarly, off-farm wage labourers are not engaged in their own cultivation nor livestock rearing but their main activity is based on wage labor not directly related to agriculture, such as factory or construction. Wage labourers with a farm are engaged in their own cultivation and/or in livestock rearing, with their activities spread between their own farm work and labour they do for others. Finally, the category "farm and self-employment" refers to people who have their own income-generating activities. Although the literature depicts well the main categories of livelihood activities found in the state of Odisha, they fail to address the complexity of livelihoods, especially how households' access to livelihood capitals is associated with specific livelihood systems.

The aim of this chapter is to explore livelihood systems in the study area and to explore the complexity of its components and determinants through a "bottom-up" lens, which means that knowledge was co-created with several rural communities during an in-depth fieldwork in the Mahanadi Delta, India. This chapter intends to address five specific objectives that provide the necessary qualitative background to answering the overarching aim of the thesis. The first objective of the fieldwork is to analyse how communities perceive the resources they have access to and which role they are playing for their livelihoods. This objective leads to the differentiation of private goods (household capitals) and common-pool resources (community capitals), which lays the background for the following chapters. The second objective is to identify if participants associate specific livelihood capitals with specific livelihood strategies. The third objective is to bring the different components of livelihood systems together to draw up a profile of livelihood systems and to identify what are the most vulnerable types of livelihoods according to the local communities. The fourth objective of the fieldwork is to analyse how external shocks affect communities and what are the coping strategies that households put in place after facing an agricultural loss.

The first section of this chapter presents in details the methods put in place to generate knowledge with the communities, which are key informant interviews and participatory approaches. The following section presents a summary of the results and then provides a detailed analysis of

livelihood components and of the external factors that influence them. The remaining part of the chapter discusses the findings and draws conclusions that will be used for future work.

3.2 Materials and methods

To conceptualise the complexity of livelihood systems in the case study, an in-depth qualitative fieldwork was conducted between February and May 2016 in the Mahanadi Delta in India. A number of activities were carried out, such as key informant interviews at the State level, rapid rural appraisals in different communities and a detailed review of the local and central policies and schemes (cf. Chapter 2). The following raw materials are compiled in Appendix: interview guides (Appendix A), transcripts of the semi-structured interviews (Appendix B) and summary reports from the rapid rural appraisals (Appendix C).

3.2.1 Key informant interviews

Semi-structured interviews with key informants were conducted during the first phase of the fieldwork. Key informant interviews are helpful to understand cultural differences (Crabtree and Miller, 1999; Dunn and Interviewing, 2005) local concepts of development, spatial distribution of common-pool resources and agricultural systems, rural dynamics and, in the specific case of this thesis, livelihood systems (FAO and ILO, 2009). According to Crabtree and Miller (1999), the main reasons for using key informants are: "(i) to gather information efficiently; (ii) to gain access to information otherwise unavailable to the researcher; and (iii) to gain a particular understanding or interpretation of cultural information." For the specific case of this study, two main reasons justify the choice of key informant interviews: to gather information in a cost-effective manner and to gain a particular understanding of rural livelihoods and climate variability in the Mahanadi Delta. One major drawback of this approach is that key informants might have a biased opinion that is unlikely to represent the view of those individuals in their community (Marshall, 1996). To mitigate this shortcoming, a diversity of key informants were chosen to cover several opinions, and general questions about their organisation were asked to understand their frame of reference and their potential bias.

In this chapter, the term key informant refers to organisations or people who have a local knowledge of agricultural systems, climatic issues and rural development in the Mahanadi Delta. They also are aware of the power relationships at stake in rural Indian villages and of the spatial distribution of key social, economic and biophysical characteristics across the delta. Different types of institutions were considered, such as public institutions, research centres, international and local organisations. To select them, a review of the institutions working in the field of rural development, climate and agriculture was conducted, based on academic and grey literature and on web searches to select the most relevant offices for this research. In-country research partners also made recommendations about the most relevant stakeholders to meet.

After contacting the organisations that were found to be relevant, availability and interest of interviewees led to the identification of the final key informants.

During each interview, general information about the organisation was discussed, such as its history, frame of reference, structure and governance, mission and area of intervention. A review of the activities led by the agency was then conducted to discuss their findings, their perception of the main livelihood zones, of the impact of climate variability on livelihoods and of people's coping strategies in response to climate variability. Finally, opportunities for cooperation were discussed, concerning data sharing and research dissemination. The following outputs were obtained thanks to the key informant interviews: (i) a deeper understanding of the organisations working in the area and of their activities; (ii) a participative map and typology of the livelihood zones and strategies; (iii) an idea of the main impact of climate variability and main issues for rural households; and (iv) a strategy to disseminate the findings from this research.

3.2.2 Participatory approaches

The objectives of conducting in-depth qualitative fieldwork were to characterise the importance of livelihood capitals in driving livelihood activities, to explore the role of community capitals, to analyse livelihood dynamics, to draw up a profile of livelihood systems and to understand how bundle of powers shape households' access to assets. To answer these objectives, the study focuses on qualitative methods that value and rest upon people's experiences and concepts. Group interviews were conducted as they enable to gain access to a larger pool of knowledge and as such, are specifically useful for natural resource data and understanding the influence of community amenities on livelihood systems. Reports for each community are compiled in Appendix C.

Rapid rural appraisals. Rapid Rural Appraisals enable local people to discuss and analyse their situation using their own terms. Mukherjee (2005) defined Rapid Rural Appraisals as "a family of approaches and methods to enable rural people to share, enhance and analyse their knowledge of life and conditions, to plan and to act". The purpose of the fieldwork was to highlight the perceptions and opinions of different classes, castes and gender, therefore the choice was made to use Rapid Rural Appraisals as the principal method to create primary data with the communities. Following the works of Chambers (1994), Wang and Burris (1997) and FAO and ILO (2009), different activities were used to triangulate the data collected and to cover all the aspects of livelihood systems: (i) resource mapping; (ii) social mapping, (iii) seasonal calendar; (iv) wealth ranking; (v) impact chain of external shocks and stresses; and (vi) photovoice or participatory photography (Blackman, 2007). The different participatory activities conducted in the communities led to the following outputs: (i) a typology of the main livelihood groups; (ii) a calendar of the activities for a normal year and for years with a natural hazard; (iii) an understanding of the perception of livelihood capitals by the community; and (iv) a participative map of the important community assets and of the main areas at risk. Many critics have argued that participatory processes only raise the voices and versions of the most

vocal participants, while the most vulnerable -most of the time the women and the lower castes- are overlooked (Guijt and Shah, 1998). Leduc (2009) argued that gender is a significant variable in environmental and development studies, due to the different role and perspective of men and women on related issues. As suggested by Cornwall (2003) who explored pathways to reduce the contradictions between "gender-aware" and "participatory approaches", a gender-sensitive methodology was used in the research so as to pay attention to both men and women's experiences. In each community and throughout the process to avoid the bias of capturing the most vocal participants only, participatory activities were held separately according to gender. Moreover, as discussed in Chapter 2, social relations of classes and castes shape access to assets, thus modifying the livelihood opportunities to which households have access. As a consequence, participatory activities were held separately according to caste in multi-caste village communities of multiple gradation (Kulkarni, 2001).

Participatory activities. The rapid rural appraisals were conducted with the help of a translator and a facilitator who was trained in conducting the activities, the evolution of the focus group being monitored at all time and appropriate guidance being given to both the translator and facilitator. During the first part of the participatory workshop held as a focus group, general information about the village and the evolution of its infrastructures were discussed. Differences within the community with regard to livelihood assets and strategies were then investigated. Once the different categories were identified, the proportion of households falling into each category were quantified. Visualisation techniques were used to produce a calendar of the main activities undertaken by households during a normal year but also during an abnormal year (i.e under the stress of a drought, flood or cyclone). Sampling techniques of community mapping were also used to highlight the important village assets, the main fields and the areas affected by climate stresses. The last activity undertaken with the participants was a participatory photography workshop using the "photovoice" methodology, a participatory approach that uses photography to generate research data (Wang and Burris, 1997; Blackman, 2007). Similar to other participatory methodologies, its philosophy is to nudge conventional research methods to ensure that people participate in the research but also lead the outputs (Maclean and Woodward, 2013). A training course was given to the voluntary households; one camera was shared between 2-3 households, and a total of 4 to 5 cameras were distributed in each communities. The rapid rural appraisal approach focuses on visual representations, observation and sharing knowledge, which are memory based approaches that might lead to biased answers (Chambers, 1983). Triangulation was used to overcome these issues and to reduce bias as much as possible, with the purpose to "obtain different but complementary data on the same topic" (Morse and McNamara, 2013). Triangulation offers a chance to evaluate the validity of data at the collection stage, for example by clarifying responses during the focus groups with additional questions and cross-examining data sources (Erzberger and Prein, 1997) and by using multiple sources of data to examine different aspects of a same phenomenon (Denzin, 1978).

3.2.3 Sampling strategy

A review of the stakeholders working in the delta led to the identification of a typology of stakeholders, based on their main activities or field of interest. Five groups were selected based on the aims and objectives that this fieldwork intends to address: (i) public agricultural and rural development agencies; (ii) public meteorological and spatial agencies; (iii) universities and research centres; (iv) international organisations; and (v) local organisations. In total, 14 institutions were visited. Agricultural and rural development agencies were selected to discuss rural livelihoods, agricultural systems and public policies for rural development. Meteorological and space agencies were selected to explore their datasets on climate variability, land use and agro-ecological zoning. Universities and research centres led to the identification of academic papers related to the local case study and of current research issues related to livelihoods and climate variability. International and local organisations were selected for their knowledge of the field and for their contribution in livelihood zoning, climate variability and to gain a better understanding of their actions in the field.

In total, 10 communities were visited within four districts to conduct the rapid rural appraisals (Figure 3.1). First, districts were selected according to their level of vulnerability (Nathan et al., 2008) and their location, so as to cover the whole geographical extent of the delta. Communities were then sampled based on their socio-economic characteristics (using census data provided by the Registrar General and Census Commissioner, 2011) and on the main livelihood activities conducted by households (according to the key informant interviews). The activities were conducted over 4 to 5 days in each community. To avoid collecting data driven by power relationships (due to gender, class and caste), two focus groups were conducted in parallel during each activity, one with men (led by a local man) and one with women (led by a local woman) (Cornwall, 2003; Leduc, 2009). Moreover, to reduce the bias due to power relationships, focus groups were held separately in multi-caste village communities (C1, C2, C6)

3.2.4 Reflexivity, positionality and power relations

In the field of feminist geography, it is a widely held view that researchers should be writing "with" rather than writing "about" to ensure that the views of the marginalised are represented (England, 1994; Bondi, 2003; Sultana, 2007). Similarly, in the field of development, conducting international fieldwork should require ethical research practices, especially in the settings of the Global South (Katz, 1994; Sultana, 2007). In other ways, researchers need to give special care to their ethic position by doing some self-analysis reflection and to the power relations at stake in the field. Adopting a reflexive research process allows researchers to gain a deeper and more nuanced understanding of the complex issues studied.

Building on the work of Pretty (1995), Cornwall (2003) drew a typology of the modes of participation that can be implemented while conducting participatory research. Four modes of participations are differentiated – functional, instrumental, consultative and transformative – and each one of them conveys a different positioning of the research towards participants, who

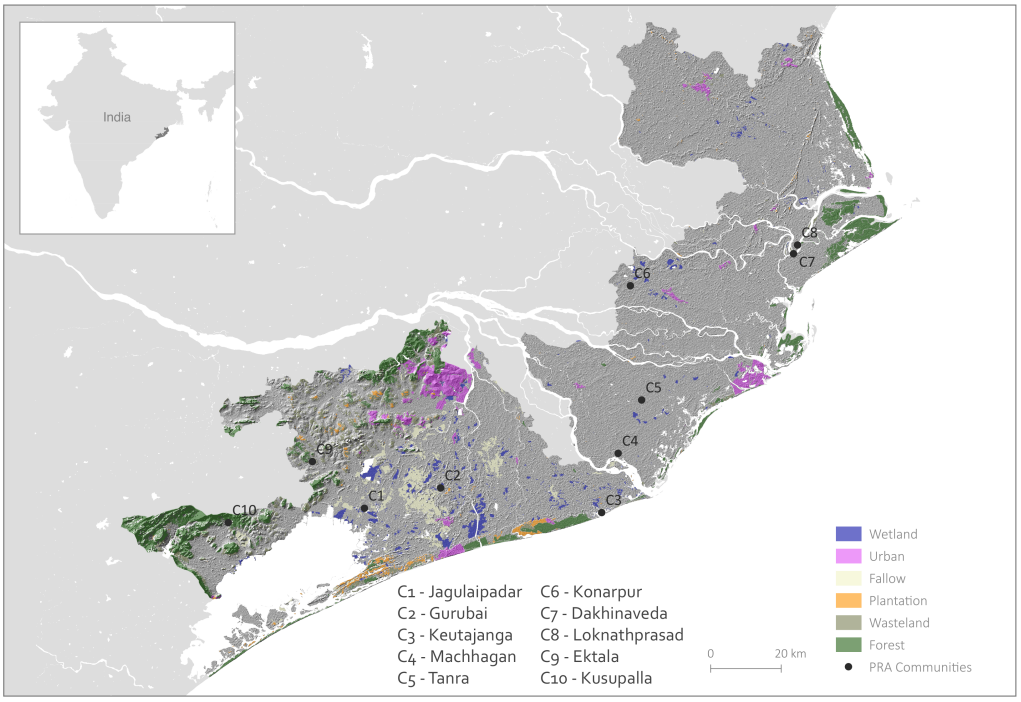


Figure 3.1: Study site and sampled communities. Rapid rural appraisals were conducted in ten communities, selected according to their level of vulnerability, their location and the dominant land cover. The map shows only marginal land cover types; when unspecified, the land cover is cropland.

are respectively seen as objects, instruments, actors or agents. This research aims to understand communities' points of views through a consultative process, so as to highlight their values and gather their opinion on the issues they face and the dynamics of their own community. In other terms, in this study, participants are seen as actors of the study rather than objects or instruments.

As discussed previously, conducting international fieldwork brings research practices into question (Katz, 1994). One sensitive subject is how to deal with differences of identities between the researcher and research participants. Sultana (2007) emphasised the importance that the researcher conducts a self-analysis reflection throughout the fieldwork process about the social, economical and cultural inequalities existing between researcher and participants. The author also held the view that understanding and accepting the differences of identities is the way towards consensual research, rather than pursuing or assuming equality. During data collection for this thesis, a special attention was given to gain a deep understanding of the differences between identities. The comprehension of cultural and socio-economical inequalities was used with objectivity and simplicity to discuss the purpose and outcomes of the research with participants.

According to Kannabiran and Kannabiran (1991) and Kapadia (1998), the social, economical and political status in India relies upon a class-based structure with landlords at the top and landless labourers at the bottom. Moreover, inequalities are perpetuated by the system of castes (Ray-Bennett, 2009), which is "an essential ingredient in the study of stratification patterns

in India's population" (Deshpande, 2001). As a consequence, such power relationships were acknowledged and taken into account throughout the study to give the opportunity to all social classes to express their opinion. As discussed earlier, focus groups were purposely held separately between men and women to enable women, who suffer from a lack of recognition in India (Deshpande, 2002), to have their say. Moreover, discussions with non-dominant castes were also held separately after general focus groups to enable people from lower castes to express their opinions and issues.

3.3 Results

The results from this chapter are presented according to the different components of the sustainable livelihood approach, which is the framework used for the conceptualisation of livelihoods and rural dynamics in this thesis (see Chapter 2). This section presents aggregated results from the rapid rural appraisals and semi-structured interviews; the primary data can be found in Appendix C. The first section presents the livelihood capitals that were mentioned as key determinant of livelihood systems by the communities and how bundles of power relationships mitigate households' access to them. The second and third parts describe the main livelihood activities that households conduct and the outcomes they generate from them. The last part gathers together the three components and synthesises them into a typology of livelihood systems.

3.3.1 Livelihood capitals influencing livelihood strategies

Four different participatory activities were conducted in the communities to characterise livelihood systems and to construct the typology. Primarily, four activities were used: (i) resource mapping; (ii) social mapping; (iii) wealth ranking; and (iv) photovoice. From this qualitative data, a pattern of the key livelihood capitals arose; each one of them was then gathered into one of the five following categories: (i) natural; (ii) human; (iii) physical; (iv) financial; and (v) social. Based on the activities conducted with the participants, the distinction between its household-level and community-level components is made for each capital.

Natural capital. According to the participants, there were three main components that fell into natural capital. These were, by order of importance: (i) agricultural land, which was mentioned as both community and household capitals; (ii) access to fresh water, which was considered as a community capital; and (iii) access to forest resources, considered as a community capital.

The most important component raised by the participants was land, used for agricultural purposes. Different characteristics fell under this natural capital component: (i) the size of land available to one household (household capital); (ii) the ownership status of this land (household capital), which is shaped by social relations of class and caste; (iii) the size of cropland, pasture

and fallow available in the community (community capital); and (iv) the topography and agro-meteorology of the land (community capital). The number of acres available per household was, according to the participants, the capital with the greatest influence on households' choice of a livelihood strategy. Indeed, households who had access to a greater number of acres (two acres and above) produced enough to be food secure during the whole year. The rest of the production could be sold or the extra land could be used for commercial crops such as cashew-nuts cultivation, betel (leaf used in paan for chewing) or coconut plantation. On the contrary, households with little access to agricultural land (less than one acre) could not produce enough food to be food secure, hence they had to go for extra income-generating activities to reach food security. Land ownership was also raised as a determining capital for livelihood strategies: share-croppers had to give a part of their production to the land owner (around 50% of the harvest), who are usually from higher castes. As a consequence, a share-cropper with access to one acre of land had, in fact, a production of only half acre of land (despite working on one acre of land).

> "A sharecropper with 1 acre of land has to give half of the harvest to the owner, who is from outside the village most of the time."
>
> *- Male participant, community C8 -*

The total area of agricultural land (including cropland, pasture and fallow) was perceived as a positive community asset, especially in remote communities. According to participants, a greater area of cultivated area in the village enabled the creation of a supply force that would attract traders to come. For example, in the community C10, it was the fact that many households decided to breed goats that led traders to come and buy them (Appendix C). Interestingly, households who were engaged in non-agricultural activities also confirmed that a greater total surface of agricultural land in the village catalyses economic activities and livelihood opportunities. For agricultural households, the topography of the village was perceived as a key resource or as a key problem depending on the community visited (Table 3.1): communities who only had access to high lands for agriculture could cultivate their crops during one season only (*kharif*) and had to leave the land barren during *rabi*, while the one with access to low land could cultivate two crops per year (with an associated increase of flood risk).

Table 3.1: Main types of land in the Mahanadi Delta based on topography. As defined by Odisha's department of agriculture and farmers' empowerment (source: authors' interviews).

Land *(type)*	**Cultivated area** *(10^5 hectares)*	**Paddy** *(%)*	**Characteristics**
High	29.14	36	Drought-prone, no irrigation, low yield, usually one season
Medium	17.55	91	Flood-prone (flash floods), lower yield than low land
Low	14.82	98	Flood-prone (water logging), irrigated, high paddy yield

Beside land, communities raised the importance of access to open-water resources and to forest resources (community capitals). Proximity to a lake, a river or the sea gave households the opportunity to diversify their livelihood activities and food security through fishing, shrimp

farming or kitchen gardening (manual irrigation from local ponds). Concerning forest resources, different products were traded, such as timber (wood, charcoal) and non-timber forest products (bamboo, *sal* seeds, *kendu* leaves and *mahuwa* flowers).

Physical capital. At the community level, road connectivity and proximity to marketing outlets appeared to be the most important assets. At the household level, access to productive assets (for agriculture, fisheries, or handicraft) and to means of transportation were the most important assets raised by participants.

Having access to all-weather transportation infrastructures (roads) was perceived as a factor that improves working opportunities through access to marketing outlets (traders are able to come to buy goods directly in the community). Although households benefit differently from such assets depending on their wealth and social networks, proximity to a marketing outlet and availability of electricity in the village were mentioned as key determinants to develop income-generating activities. A marketing outlet could be of different types, from general (such as a market) to more specific (such as a cooperative or society), proximity to an outlet acting as a catalyst for activity diversification, such as milk or raw-fish production.

> "After the creation of the milk society 7 years ago, we started to breed Jersey cows because they give more milk. Now we sell our milk there everyday, and it is it located at a walking-distance."
>
> *- Male participant, community C4 -*

The availability of irrigation canals and tanks in the community, mainly associated with the green revolution, plays a major role into mitigating the effects of climate variability on agricultural production (through droughts or floods) and was mentioned as a key community capital. Such irrigation facilities are considered as common-pool resources because they were publicly funded by the State Surface Flow Irrigation Schemes and most households are able to benefit from them regardless of their class or castes. For example, participants from non-agricultural households mentioned that they were able to collect water from the canals to irrigate their house gardens for their supply of vegetables.

Access to productive assets, such as draft animals, equipment (seeds, fertilisers), machinery (tractor with plow, water-pump, fishing boats) and means of transportation (bicycle, motorcycle, car), was also a raised by communities as determinants for their livelihoods. Means of transportation (either private or public) allowed households to look for new marketing outlets for their production and also to reduce travel times to nearby services. For the participants, investing in productive assets would enable them to increase their agricultural or fishing productivity, thus increase incomes (for the same workforce and time spent). For example, some households were able to cultivate during *rabi* thanks to irrigation systems they had invested in, such as water pumps.

> "We can't cultivate during *rabi*, there is water scarcity [...] I am the only one in the community who cultivates during *rabi* season, thanks to the water-pump I bought. I have 3 acres and I produce pulses, ginger, cucumber, sunflower and watermelon."
>
> *- Female participant, community C9 -*

Human capital. According to the sampled communities, workforce (considered as a household capital), education (considered either as a household or community capitals) and sanitation facilities (considered as a community capital) were perceived as the most important assets to take into account in the human capital.

Due to the gendered division of labour (Chapter 2), male participants described male workforce availability as the most important component of human capital for livelihood opportunities. Men were found to be in charge of cultivation and of earning incomes (through migration or daily-wage employment). For example, a household with only one man tended to engage in agriculture and would not be able to migrate as he had to look after the farm. As a consequence the household would look for daily-wage labour to diversify their incomes. On the contrary, if the household had more than 2 men, at least 1 man stayed to look after the farm and the rest were going for migration for 6 months (off-*kharif* season). The overall number of active members in the household also had a great influence on the range of livelihood activities the household could put in place. A great number of members allowed the household to cope faster in the case of an external shock, as all members could look for income-generating activities (mainly daily-wage labour). However, it was perceived that "large households" was a negative asset, as it was creating extra expenses for the households and increased the risk of food insecurity (decreased cropland area per person and thus problems of food security). It is interesting to note that women did not mention male workforce as a capital but they raised it as a social constraint that prevented the household to diversify their activities.

> "We didn't inherit from any land, we do share-cropping. We have three daughters, so my husband is the only man in the household. He cannot go for migration, he has to stay to take care of the household and of our agricultural land. So he is doing daily wage labour and we also rely on cow milk production."
>
> *- Female participant, community C4 -*

At the household level, the presence of educated and skilled members was perceived as driving households towards a diversification of their activities. Actually, educated members were more likely to get a permanent employment in the public sector, such as teacher or administrator (at the *panchayat* or block level), or in the private sector (hairdresser, driver, etc.). They also were more likely to set up their own business such as service provider or trader. In some cases, there were also some specific skills that enabled members to go for "skilled" migration. The most famous example raised during the rapid rural appraisals were the plumbers from Pattamundai in Kendrapara, commonly called the "Plumbing Capital of India", who were going on long-term

migration in other States of India and abroad and who were sending remittances back to their household in the community.

Finally, one of the main issues raised by the women was their lack of access to community amenities, such as schools, sanitation facilities (latrines, drinking water) and to health facilities (health centre, hospital). According to them, a better access to health facilities and to safe water infrastructures would diminish the risk of health problems, while access to schools would enable their children to spend their day there, giving them time for other activities and increasing their future livelihood opportunities. Overall, they argued that proximity to these community amenities would enhance their labour capacity.

Financial capital. According to the participants, the main financial resources of one household are invested in protective assets such as electronics (TVs, radios, phones), furniture, clothing and jewellery. For household who were not involved in livestock rearing, ownership of cattle and goat was also considered as a protective asset, used as a saving and insurance instrument. Protective assets were to be sold if the household faced an external shock (crop failure, death, disease, wedding). Having access to financial services was mentioned by the participants as providing two different services, savings and loans, although only better-off households were able to have savings in a bank account. Access to loans allowed households to invest in their means of production (agriculture or other income-generating activities) or to cope with external shocks and reduced the likelihood of distress migration.

Participants primarily mentioned the importance of having access to banks in order to obtain formal financial services. However, due to the privatisation of these institutions after the liberalisation, tenant cultivators are denied access to formal credits. The inability for smallholder farmers to access formal credit forces them to rely on "informal sources", such as the traders who provide agricultural inputs or local moneylenders with usurious interest rates. Such a dynamics pushes farmers into a long-term indebtedness, which undermine their future financial capital and livelihoods. At the community-level, proximity to a bank was also raised as critical when it comes to state schemes and pensions: for example households needed a bank account in order to get paid for work they conducted under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). Female participants emphasised the importance of Self-Help Groups as alternatives to traditional financial services as they argued that they could get access to loans through them.

Social capital. Participants mentioned the importance of social groups such as Self-Help Groups (SHG), youth and farmers groups to give them new income opportunities or to increase their migration options. These groups are considered as community-level assets, which enhance social networking that might lead to alternative livelihood opportunities. Participants, and especially women, showed a strong interest in SHGs, which is a way for them to build strong social links and to build their capacities and empower themselves. It also emerged from the discussion that availability of recreation facilities, such as *chaupal* (public community space

or building) or sport fields was an important community capital that enabled to build strong kinships and that also prevented younger males to migrate out of the village for work.

Some participants felt that family connections were a key asset to find job opportunities and to be integrated into migration networks, arguing that household size helps to expand networks. While discussing with widows, it emerged that unmarried or widowed households were to suffer from social exclusion, especially from community groups and unions. Interestingly, no participants mentioned the issues of scheduled castes and tribes until a conflict emerged during one of the activity. Separate discussions were then held with the participants involved in the incident and the theme of social balance emerged. Participants from a caste in minority in the community reported that the unbalanced ratio between general castes and scheduled castes, tribes and other backward castes had led to one caste taking over the other and to the exclusion of some of them from the community social groups such as SHG. As a consequence, participants felt that their community networks were impoverished.

> "In our hamlet, scheduled caste is the main population; we general caste are a minority now. SC are the majority and they have a strong voice so they have the power. As general caste, we do not benefit from governmental schemes and subsidy loans for SHG, whatever is left, we get that. So the SC women asked us to leave SHG groups, there are no more mixed SHG groups now. We keep silence to keep no tension, but if we want to raise tension, then there will be tension."
>
> *- Female participant, community C1 -*

3.3.2 Livelihood activities

Wealth ranking, "photovoice" and seasonal calendar were used to understand the main livelihood activities that households put in place. Following Savath et al. (2014a)'s typology, livelihood activities were grouped in two groups: on-farm and off-farm. On-farm activities are the activities which are related to farming or agriculture, while off-farm activities are defined as any activity other than farm-related (manufacturing, shopkeeping, transport, etc.).

On-farm activities. On-farm activities were the main livelihood activities put in place by participants, with their outcomes used for subsistence (through self-consumption) and/or commercial (through trade) purposes. Four types of activities emerged from the rapid rural appraisals: (i) agriculture (ii) livestock rearing; (iii) fishing; and (iv) forestry.

Agriculture was mentioned as the main activity for most households, however a distinction was made between commercial and subsistence agriculture. Subsistence agriculture consisted in the cultivation of staple crops for the household's own consumption: most of the time paddy during *kharif* and pulses (black and green gram, dal) during *rabi*. Commercial agriculture consisted in the cultivation of non-staple high-value crops that farmers sell to traders or cooperatives.

Participants described high-value crops as betel, coconut plantations, vegetables, fruit trees and cashew-nuts plantations.

Livestock rearing was seen by participants as a complementarity activity, usually combined with farming. They said that the outcomes from livestock were sold in the market or to cooperatives and that they could be of two types: dairy or meat production. Cow breeding was used for dairy production purposes and existed only in communities located near a milk cooperative. Goat breeding was used for meat production, with traders coming directly to the communities to buy young goats from farmers.

According to participants, fishing activities were only put in place alongside agriculture. Two types of fishing activities were highlighted: aquaculture and capture fisheries. Capture fishing was the only type of fishing activity that participants were engaged in, either in the Chilika lake or in rivers. Men emphasised the fact that capture fishing did not require much investment. Some participants owned fishing equipment such as boats (sailing or motor) but they acknowledged that the majority of fishers rent such equipments or do not use any. Men interviewees argued that aquaculture required much more investment (economic and time-wise) and was conducted by the wealthiest households.

Participants in communities located near forests (C9 and C10) indicated that forestry was a key resource for their livelihood strategy. Extractive activities of timber products (wood) and non-timber forest products (NTFP) such as seeds, roots, leaves, fruits and flowers were conducted by households in these communities to generate incomes. They indicated that *sal* seeds were picked by communities and then sold to traders who buy directly from the farmers, or sometimes sold directly at the market. *Kendu* leaves were processed directly in the communities to make Indian cigarettes called *beedi* (leaves are wrapped around tobacco). Participants mentioned that they were drying *areca* palm tree leaves and then were selling them to local restaurants to be used as disposable plates. Finally, *mahuwa* flowers from *madhuca longifolia* trees were found to be used by tribal communities for medicinal and alcoholic purposes: flowers were dried and fermented to produce a country liquor called *mahuwa*.

Off-farm activities. Off-farm activities were indicated as very important for livelihood diversification and coping to shocks, which were grouped into three main types: (i) salaried employment; (ii) self-employment; and (iii) temporary employment.

Salaried employment was quite uncommon in the communities visited, and consisted of public employment (government, administration, teachers) for a only a few dwellers. Long-term migration (over one year) to another State or to other countries (United Arab Emirates, Oman, Saudi Arabia) was mentioned by a few participants. They explained that such a strategy was put in place by households with a strong labour force that has specific skills (human capital), such as the skilled plumbers from Kendrapara district and that remittances were sent regularly to the migrant's household. During the rapid rural appraisals, a few participants were retailers, wholesalers or other service providers, which can be classified as self-employment. Although

they argued that it did no guarantee them regular wages, they were getting greater income than daily-wage labourers, and more regularly.

Participants argued that seasonal labour migration did not guarantee incomes from one season to another but guaranteed a wage for one season. This unskilled migration (construction work, fishing, cotton factories) appeared after the super-cyclone in 1999 and was used to get rapid income for household expenses (mainly food) or to repay loans.

> "We started migrating 10-15 years ago, mainly because poor harvests and droughts. We get an advance from middlemen before migrating and then after few months we migrate to work. With the money, we repay loans or we buy paddy."
>
> *- Male participant, community C10 -*

Daily-wage labour was the second type of temporary employment raised by communities. Households who were engaging in this type of activity were classified as "poor" in the wealth ranking activity, because people would look for daily-wage labour when they had no other option. Participants indicated that this type of work was unskilled (agricultural labour, construction work and junk collection) and available in the premises of the community or nearby.

3.3.3 Livelihood outcomes pursued by households

Wealth ranking was the main source of information to understand the outcomes pursued by households. The following three categories arose from the focus groups: (i) achieving food security; (ii) improving housing conditions; and (iii) investing in protective assets.

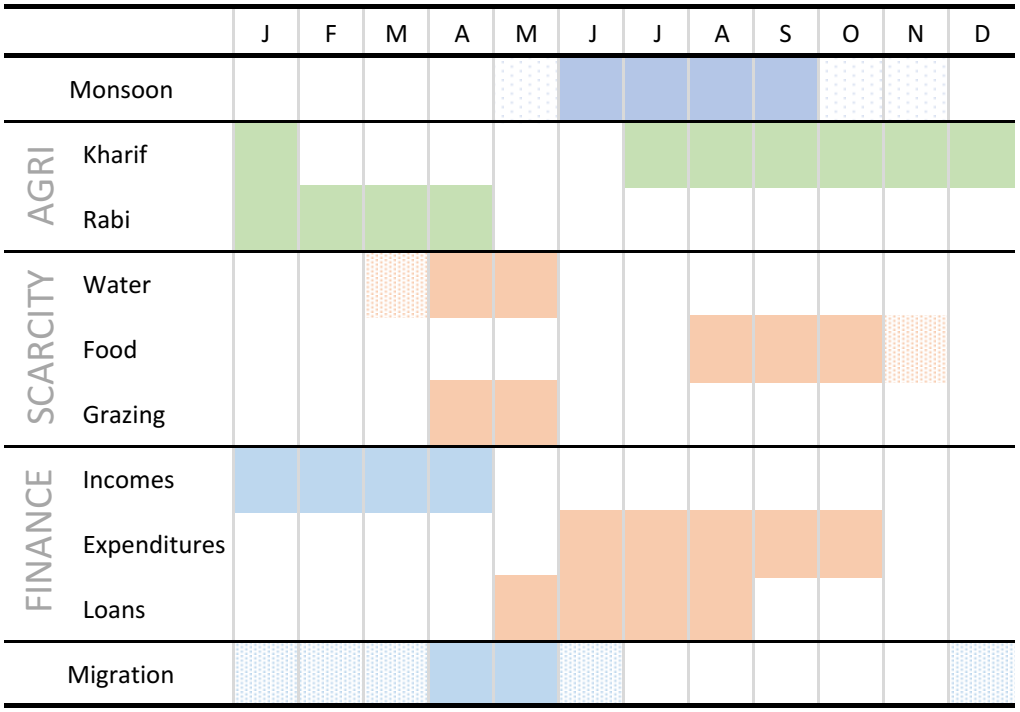
Food security, through the level of self-sufficiency in paddy production, was raised by the participants as the most important outcome for households to achieve. According to the participants, food security levels could range from total insecurity (for landless households) to all-year security (for households that own and cultivate more than 1 acre). Participants also highlighted housing condition as one of the indicator of wealth within communities. Three types of housing conditions were differentiated: (i) *pucca*; (ii) *asbestos*; and (iii) *kutcha. Pucca* houses were indicated as the best condition of housing, with walls and roof made of burnt bricks and cement. *Asbestos* houses were defined as intermediate quality housing, with walls made of mud or cement and the roof made of metal sheets, which made them very sensitive to natural hazards. The term asbestos originates from the previous use of asbestos for roofing but now refers to metal roofing sheets (Registrar General and Census Commissioner, 2011). The last category, *kutcha* houses, was the worst condition according to the communities, with walls made of mud and the roof made of thatch. It appeared that one of the main aim pursued by households concerning housing condition was to convert from a *kutcha* house to a *pucca* or *asbestos* one. Finally, participants said that a great part of the extra-incomes earned by households were invested in self-insurance mechanisms such as the ownership of protective assets, such as monetary savings, livestock, electronics (TVs, radios, phones), furniture, clothing or jewellery.

3.3.4 Processes relevant to livelihoods

Three different types of modifying processes emerged from the fieldwork: seasonal processes, coping processes under external stresses and long-term processes.

Seasonality. The critical period of "lean season" ranged from August to October (Figure 3.2) and was characterised by low stocks of rice (due to poor storage facilities), unavailability of daily-wage work (because of the monsoon) and households' need for fast cash ahead of the annual festivals (September/October). Moreover, households' finances were particularly low during this period as it followed the preparation of the *kharif* season for which they had to purchase agricultural inputs (seeds, fertilisers) and pay for agricultural services (ploughing, irrigation). As a consequence, the majority of participants agreed with the statement that expenditures were greater during this time of the year (June to October) although most of their income was earned at the end of the cropping seasons, between January and April. To overcome this need for "fast cash", households had to contract loans (usually from money lenders) or to ask for a salary advance from middlemen who would organise the seasonal labour migration. In that case, the household would get their salary during the lean season but, in exchange, one man of household had to migrate through the middleman's network between December and June. In both cases, interest rates were high and households were being trapped in a debt-loop: they had to sell part of their paddy harvest to pay back the loans and were likely to face the same situation the following season.

Table 3.2: Summary seasonal calendar in the Mahanadi Delta. The critical period of "lean season" ranges from August to October and is characterised by low stocks of rice, unavailability of daily-wage work and an urgent need for cash ahead of the annual festivals.



External shocks and stresses. Throughout the interviews, it appeared that social networks played a very important role for households because they facilitated their access to financial services and job opportunities. In particular, social obligations and celebrations such as weddings, births, deaths or cultural and holy festivals, were indicated as essential to build and maintain strong social networks. During such celebrations, households had to offer presents or food to their relatives, which can be interpreted as a trade-off from financial to social capital. Political issues, such as the difference of political party between the community leader and the *panchayat* or block leader, were also mentioned as external stresses for livelihood systems that led to delays in the collection of pensions and reduced households' access to public schemes.

> "Our political leader is from a different party than the panchayat leader so we haven't had access to our pensions and to governmental schemes for more than 2 years now."
>
> *- Male participant, community C6 -*

To cope with such shocks, households reported to engage in wage labour or to migrate to find paid work. For households who already relied on seasonal migration, a shock led to an increased number of their members to migrate For households relying on daily-wage labour, a shock forced all members to undertake daily-wage labour to allow men to go on seasonal migration. The strategy of going on seasonal migration was initially triggered by the super-cyclone 1999, following which households had to migrate to cope with the damages. Since the cyclone, households with enough human capital have kept seasonal migration in their activity portfolio, unskilled seasonal migration becoming an adaptation strategy to the uncertainty of crop production for them.

> "After the super cyclone 1999, we lost all our crops. So we took loans from the bank and we started to migrate to look for jobs. Now only the better-off households still migrate every year."
>
> *- Male participant, community C3 -*

Seeking alternative livelihood activities was also implemented at the group or community level. For example, in Keutajanga, villagers built a community pond to develop pisciculture so as to diversify their activities that were mainly crop-based. Incomes from pisciculture were either reinvested in the activity, or given as an interest-free loan to villagers. Many Self-Help Groups also created livelihood alternatives for their members, such as production of handicrafts or trading activities (Figure 3.2).

3.3.5 Vulnerable livelihood systems

In this section, the results are summarised into a conceptualisation of livelihood systems and trajectories in the Mahanadi Delta. The combination of one household's access to livelihood



Figure 3.2: Photovoice showing alternative livelihood activities initiated by SHGs in community C1. Sewing crafts (left) and storage for fish sales (right)

capitals with the portfolio of livelihood activities its members put in place leads to the identification of a livelihood system that can be classified according to its overall dynamics (see Chapter 2): stepping-up, stepping-in, hanging-in and dropping-out. Table 3.3 summarises the main characteristics of each livelihood category.

Table 3.3: Typology of household livelihood systems in the Mahanadi Delta. Systems are classified according to households' overall dynamics. The two categories hanging-in and dropping-out are considered as the most precarious livelihood systems.

	Stepping-up *Accumulating*	**Stepping-out** *Diversifying*	**Hanging-in** *Maintaining*	**Dropping-out** *Surviving*
CAPITALS				
Natural	Land owner $\geq$ 1 acre	Share-cropper $\leq$ 1 acre	Share-cropper $\leq$ 1 acre	- -
Human	Workforce $\geq$ 3 Skilled&Unskilled	Workforce $\geq$ 2 Unskilled	Workforce $=$ 1 Unskilled	Workforce $\leq$ 1 Unskilled
Physical	Own equipment Motorised Vehicles	Rent equipment Manual vehicles	Rent equipment Manual vehicles	- -
Financial	Cattle, goats Bank savings	Few cattle, goats -	Few goats -	Sometimes goats -
Social	Political network Extended family	Migration network Family	- -	- -
ON-FARM ACTIVITIES				
Agriculture	Subsistence Commercial	Subsistence	Subsistence	$\times$
Livestock rearing	Yes	Yes	Sometimes	No
Fishing & Forestry	Self-consumption Commercial	Self-consumption Commercial	Self-consumption	$\times$
OFF-FARM ACTIVITIES				
Type of employment	Permanent	Seasonal	Daily	Daily
OUTCOMES				
Food security	10-12 months	6-10 months	6 months	Insecurity
Housing	Pucca	Asbestos	Kutcha	Kutcha
Protective assets	TV/Radio Jewellery	TV/Radio	$\times$	$\times$

The "stepping-" categories represent households with diversified activity portfolio that are the less vulnerable livelihoods to external shocks and stresses. The "stepping-up" strategy represents households who use their current incomes to invest in productive assets to expand their ongoing activities as a way to improve their livelihoods. These households were usually

considered as "better-off" by the participants. Some of their members often have a permanent employment: (i) in the public sector (government administration, teachers, etc.); (ii) in the private sector (drivers, plumbers, etc.); or (iii) self-employed (businessmen). Regular wages are then invested into the productive assets of the household (agricultural inputs, equipment, vehicles, other tools) to improve and secure their livelihoods. Households who are "stepping-out" follow a strategy of investment into assets that will enable them to move into different activities that should lead to higher or more permanent returns. As an example, incomes from agriculture can be invested into training or into traveling expenses (for migration) to diversify their portfolio of activities and get higher incomes in the future.

The last two categories represent the most vulnerable livelihoods in the Mahanadi Delta. Strategies falling into the "hanging-in" category represent the households who are engaging activities to maintain their actual level, without investing into any new productive assets nor any alternative livelihood perspective. In such a strategy, incomes are used to buy agricultural inputs (on a same basis than previous seasons), to repay loans, to buy food or to cover daily-life expenses. The last category is "dropping-out" and represents households with either a weak human capital (with disabled members, elderly or are female-headed) or located in communities without job opportunities. Because of their lack of community physical and household human capital, they only engage in daily-wage activities or are unemployed (Figure 3.3). Their incomes are used for daily-life expenses only, with the only perspective of surviving.



Figure 3.3: Photovoice displaying precarious livelihoods. Unemployed youth playing cards who are waiting for labour: "if there is a job opportunity then they would take it" (left). Daily labourers doing construction work (right).

3.4 Discussion

This part of the chapter discusses the findings which emerged from the qualitative analysis presented previously. It summarises the findings on livelihood systems by discussing the associations between capitals and activities and their dynamics in view of existing social relations of class, castes and gender.

3.4.1 Associations between livelihood capitals and activities

The findings from rapid rural appraisals show that participants perceive that there is a link between households' access to livelihood capitals and their choice of a livelihood activity.

Household-level drivers. On-farm activities as main livelihood are driven by a great access to natural and physical capitals. Large farms provide higher incomes to farmers and therefore, increase farm survival, as suggested by Kimhi and Bollman (1999). Quality and quantity of agricultural land have a positive effect on engaging into cultivation, while having access to productive capital is likely to lead to a specialisation into commercial agriculture. The caste system also plays a role in the choice of conducting an activity, for example fishing: fishermen is perceived as a job for the low castes. As a consequence, dwellers from higher castes do not go fishing, even if they have access to water resources and even under the circumstance of an external shock.

> "We can't go fishing because we are not from the fisherman caste, we are from the general caste."
>
> *- Male participant, community C3 -*

The drivers of off-farm activities mainly fall under human, financial and social capitals. Permanent employment and self-employment are both positively influenced by the level of education of the household's members and by their ownership of protective assets. Starting a business or migrating requires a financial input, either to buy equipment to start the business, or to pay for transport and accommodation for migrants. Moreover, being able to migrate also depends on the strength of social networks (or migration networks) and on the communication facilities one household has access to. Households take the decision to have one of their members migrating only if there is a man that can stay to take care of the farm. Availability of male workforce is a key driver of migration and more specifically of seasonal migration.

Community-level drivers. According to the findings, livelihoods were found to be shaped by their geography and access to common goods, managed at the community level. The literature points out that access to common-pool resources is shaped by social relations of castes, lowest castes being prevented to access water or forest resources (e.g. Borooah et al., 2014). However, the rapid rural appraisals conducted within this study showed that access to norms of self-identity, with middle-castes preventing themselves to use some common-pool resources, as it might be seen as an activity for lower castes, confirming previous studies (e.g. Sankaran et al., 2017). Similarly, regarding irrigation facilities, although clandestine encroachment and tampering with the water course can be found among wealthy farmers of dominant castes, who rely upon their status to assuage dissent and on political connections to suppress official complaints, inequalities in water access depend more on the ability to monopolise groundwater supplies by digging expensive and uncertain bore-wells than on monopolisation of tank water.

The total agricultural area of the community was perceived as a stimulating factor for cultivation, as it motivates traders to come buy the goods directly in the community. Evidence suggests that an increase in the access to operational land reduces the tendency to close down farms, thus reducing the likelihood of farm exit and of households engaging in precarious livelihoods (Glauben et al., 2006; Bhandari, 2013). The total agricultural area in the village has a positive effect over the possibilities of other capitals: it can create synergies between farmers to buy agricultural equipment (physical capital), invest into irrigation infrastructures (physical capital) or in can increase their bargaining power (Courtois and Subervie, 2015; Agarwal, 2018). The success of most agricultural activities depends on the capacity of households to sell their products and so is also dependent of a good road connection with an outlet nearby. Access to water resources is a *sine qua non* condition to conduct fishing activities, but making a living out of it also requires an access to outlets to sell the products and to private fishing equipment. Concerning forest resources, activities are independent of the existence of an outlet nearby, they rely on good road connections and on the area of forest available, which provides households with high value-added products (*sal* seeds, *kendu* leaves, *mahuwa* flower). Selling these products to traders that come directly to the communities to buy the goods enable households to earn extra income and to cope better with external shocks. Access to communal lay land, defined as customary communal tenure that can be used for animal grazing, is an incentive to put in place livestock rearing activities. Figure 3.4 confirms these findings and shows that *Keutajanga* (C3) and *Kusupalla* (C10) have a higher proportion of dwellers involved in cultivation, which corroborates the fact that they have a great access to community natural capital (large total cropland area, access to forest and river).

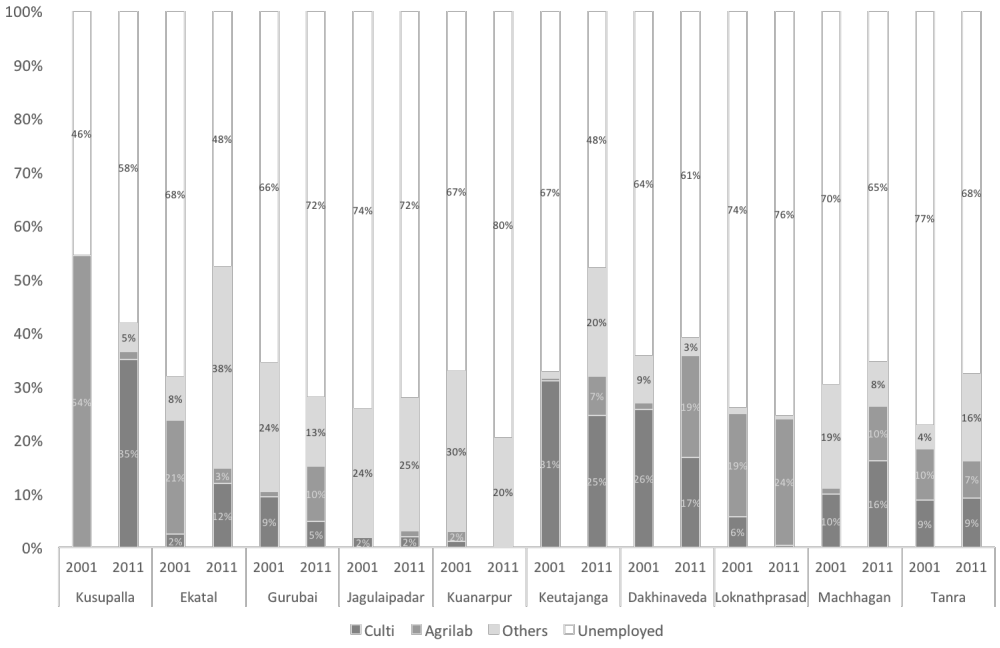


Figure 3.4: Proportion of dwellers according to their main livelihood activity. Figures for the four activities monitored by the census of India in 2001 and 2011 for each of the ten sampled communities in which the rapid rural appraisals were conducted. Based on data from the Census of India 2001 & 2011 (Registrar General and Census Commissioner, 2001, 2011).

The main difference between the two communities relies upon the proportion of dwellers involved in "others" activities, which can be attributed to their road connectivity, *Keutajanga* benefiting from the proximity to a trading-centre (Puri), while *Kusupalla* is more remote. Proximity to trading-centres with community amenities was perceived as driving off-farm activities, which can be seen in Figure 3.4 with *Jagulaipadar* (C1) and *Konarpur* (C6) are mainly inhabited by people implementing "others" activities as a way to make a living. This can be explained by the very good connectivity and the proximity of a market for both communities. It is interesting to note that *Dakhinaveda* and *Loknathprasad* have a very different structure of livelihood activities even though they are located nearby, thus should benefit from a similar access to natural and physical capitals. A possible explanation for this might be that both communities suffer from land erosion, Loknathprasad being much more affected due to its exposure to three rivers whereas Dakhinaveda is exposed to one. As a conclusion, participants perceived that their access to community capitals have an influence on the type of livelihood activities they put in place. Natural and physical community capitals are perceived as drivers of on-farm activities, while the combination of social, financial and human community capitals seem to induce off-farm activities.

3.4.2 Livelihood trajectories: links between households and communities

In the Community Capitals Framework, Emery and Flora (2006) highlight the interdependence, interaction, and synergy among the capitals. Their findings suggest that the use of one capital can have a positive or negative effect over the quantity and the possibilities of other capitals. For example, investing in one capital might help strengthen one or more of the other capitals, as pointed out by Flora et al. (2015): "each form of capital has the potential to enhance the productivity of the others." Similarly, there is also a link between trajectories of capitals and livelihood opportunities. Bhandari (2013) showed that increased access to physical resources such as non-family services may positively influence farm exit, as the development of community resources (schools, health services, banks, cooperatives, bus services) may provide off-farm employment opportunities to individuals.

The findings from this chapter suggest that having a great access to both physical and natural capital lead to an intensification of current agricultural practices for commercial purposes. Large amount of land enable dwellers to expand their farm and their access to physical capital enable them to maximise their practices and to sell their production. In the case where communities have a low physical capital, households are more likely to diversify their production, aiming at high value-added products such as certain types of animal husbandry, fruit production or high-value crops (e.g. cashew-nuts). In contrast, it is likely to see an activity shift and a reorientation towards off-farm activities within communities with a low natural capital but a strong physical capital. However, dwellers from such communities keep agricultural activities for subsistence, whereas in communities benefiting from low physical and natural capitals, households disengage totally from agriculture and are likely to out-migrate.

3.5 Conclusion

This chapter showed that most households in the Mahanadi Delta relied on a combination of on-farm and off-farm livelihood activities for their livelihoods. Four groups of livelihood activities emerged from the "wealth ranking" participatory activity, which can be linked to their degree of vulnerability to external shocks, from lowest to highest: (i) off-farm salaried employment, which ensures regular incomes and mostly consists of public employment (government, administration, teachers) and private services (bus drivers, cooks, construction workers); (ii) self-employment, such as cultivation (farmers who own their land) and off-farm business activities (retailers, wholesalers, equipment owners, bus operators, private entrepreneurs and other service providers), and which provides households with above-average incomes although it does not guarantee them to get a regular wage; (iii) temporary employment or daily-wage labour, such as agricultural labour, construction work and junk collection, amongst others, which does not give any guarantee to the household; and (iv) unemployment. Although the literature already showed that the most vulnerable types of livelihood activities are agricultural labour and unemployment (Chapter 2), this finding shows that communities themselves perceive these two activities as the most precarious livelihoods.

The second major finding was that access to livelihood capitals is perceived by local dwellers as the main factor affecting their choice of a livelihood activity. One of the most interesting result was that participants valued community capitals and considered them as key factors influencing their livelihoods, confirming the main hypothesis of this thesis. Community-level capitals, such as access to natural resources (total cropland, forest, wetlands), productive infrastructures (markets, roads, irrigation facilities), services (markets, hospitals, schools) and social assets (castes balance, recreation facilities) are significant drivers of households' livelihood strategies. The availability of one community capital create synergies amongst dwellers that can have a positive or negative effect over the quantity and the possibilities of household capitals and of livelihood opportunities, regardless of the social relation of caste and class at stake within a community. Moreover, some of these common-pool resources directly provide livelihood opportunities that can be transformed into incomes by households, whereby they have access to the appropriate household capitals to do so. The findings of this chapter suggested that natural and physical capitals were drivers of on-farm activities, especially access to agricultural land (at both household and community levels) and connectivity to markets. On the other hand, human, financial and social capitals were found to lead towards off-farm activities, especially workforce availability and low dependency ratio, access to financial services and having access to social networks, which are necessary assets for migration and off-farm employment.

The research also showed that climate variability leading to crop failure was an important external factor influencing livelihood dynamics. As a consequence of both lower yields and the absence of formal financial services, households had to contract loans from private moneylender, sell protective and productive assets, go into distress migration or take daily-wage jobs to cover the lean season. Such dynamics were found to reduce households' capacity to invest in their means of production and thus prevented the development of sustainable livelihoods. As a

response, many social schemes were put in place by both central and state governments in the last ten years, with the objective to check distress migration and unemployment by creating job opportunities. However, they do not take into account the diversity of rural communities and fail to meet households' needs, resulting in a non-use of the opportunities offered. A natural progression of this chapter is to use quantitative methods to demonstrate the spatial distribution of livelihood capitals in the delta and to characterise the associations that exist between them.

CHAPTER 4 Associations between livelihood capitals

Despite the increasing interest of the Sustainable Livelihood Framework in the field of international development and in academia and the recent call for the use of mixed-methods approach, there has been little analysis that bring together qualitative and quantitative methods over a large geographical extent. Based on findings from the rapid rural appraisals during which participants identified the key assets needed to achieve their livelihoods, this chapter differentiates two levels of livelihood capitals (household capitals and community capitals) and creates quantitative indicators that can be mapped across the delta, derived from national census data and satellite sensor data. Spatial patterns and differentials in access to livelihood capitals across the delta are examined and the associations that exist between household capitals, between community capitals, and between both levels of capitals are quantified. The results suggest that household physical capital is positively associated with household financial and social capitals but negatively associated with household natural capital, supporting the hypothesis that poor households sell part of their land when facing unforeseen expenditure. A negative association between access to community amenities and access to natural resources was also clearly supported by the findings, which means that an increased access to public amenities is usually associated with less access to natural resources. Moreover, proximity to main axes of communication is positively associated with access to community amenities but negatively associated with access to natural resources, while remoteness is positively associated with household natural capital but negatively associated with household physical and human capitals.

Results from this chapter were presented at the RGS-IBG conference “Nexus Thinking” in London (UK), September 2016 and at the Tropmet conference “Climate Change and Coastal Vulnerability” in Bhubaneswar (India), December 2016.

4.1 Introduction

Different components are included in the sustainable livelihoods framework, in particular livelihood capitals, a term that encompasses both assets and households' capabilities. As discussed in Chapter 2, the majority of studies seeking to apply the Sustainable Livelihoods Framework have mainly focused either on household-level capitals (Fang et al., 2014) or on indicators combining both household and community capitals together (Paudel Khatiwada et al., 2017). However, based on rapid rural appraisals (Chapter 3), this thesis argues that common-pool resources (community capitals) should be differentiated from private goods (household capitals) as they operate under different dynamics of decision-making, management, ownership and control. Although access to common-pool resources can be mitigated by social relations of class and caste, rural dwellers considered community amenities as determinant for their livelihood opportunities. Participants differentiated them from their own private assets, since the availability of one community capital can create synergies amongst households from the same community, which can have a positive or negative effect over the quantity and the possibilities of their private capitals and livelihood opportunities. Moreover, despite the increasing interest in spatial analyses of poverty and livelihood issues in the field of international development, there has been little analysis that brings participatory findings from qualitative methods into a quantitative analysis over a large geographical extent to map livelihood assets and characterise their spatial associations.

Two mechanisms may lead to associations among livelihood capitals: (i) one household capital is intensified by a particular community capital, as in the case of proximity to schools acting as a catalyst of people's skills and capabilities on the long-term, providing education to individual members of the community; (ii) individuals (or communities) make trade-offs between different capitals to meet their needs and mediate vulnerabilities, as in the case of financial capital that might be invested into means of production; and (iii) a given external factor may affect several capitals at the same time as with the impact of a cyclone negatively influencing common-pool natural resources and also decreasing households' protective assets. As a result of these associations, some livelihood capitals might co-vary positively, for instance community productive infrastructures may improve household financial capital by increasing their access to banks and to markets, while some livelihood capitals may co-vary negatively, as for productive infrastructures might be degrading common-pool natural resources through the expansion of the built environment. Planning strategies aiming at enhancing the economic development of a particular region need to account for such linkages to make sure that investments in one capital do not lead to the depletion of several interrelated capitals.

This chapter aims to integrate findings from the participatory analysis conducted in the Mahanadi Delta (Chapter 3) into a quantitative framework to highlight the spatial distribution of livelihood capitals and to characterise the existing associations between them (Objective 1). More specifically, this chapter answers this objective by addressing the following sub-objectives: (i) to build a quantitative indicator-based conceptualisation of livelihood capitals at both community and household levels; (ii) to examine spatial patterns and differentials in access to

livelihood capitals across the Mahanadi Delta; and (iii) to characterise the associations between household capitals, between community capitals, and between both. By doing so, this chapter presents a methodology to quantify results from rapid rural appraisals over a large geographical extent. It shows that there are associations between livelihood capitals and that some capitals are spatially clustered.

4.2 Materials and methods

This section presents the materials and methods used to quantify the findings from rapid rural appraisals during which participants identified the key assets needed to achieve their livelihoods (Chapter 3). It presents how quantitative indicators for both household and community capitals were created by using national census and satellite sensor data.

4.2.1 Data

Several sources of data were needed to proxy the different capitals highlighted by participants during the rapid rural appraisals (Chapter 3), such as environmental data, socio-economic and demographic data, infrastructure and amenities. Census and satellite remote sensing data were chosen as they are publicly accessible online, they are available at a fine resolution (community-level or finer) and cover the spatial extent of this thesis.

The demographic data used in this chapter were a subset of the 2011 Census of India (Registrar General and Census Commissioner, 2001, 2011). The data are at the community-level and consist of three sets of tables: "community amenities", "house-listing" and "population enumeration". The "community amenities" dataset includes village area in hectares, total income, total expenditure and the different infrastructures available related to education, medical, drinking water, communication, banking, recreational and cultural facilities, accessibility to the community, power supply and natural resources. The "population enumeration" tables provide comprehensive information on the population, with all the information recorded based on the twelve months preceding census enumeration. For instance, these tables provide figures about the main livelihood activity of each individual (cultivator, agricultural labourer, entrepreneur, other) and its frequency ("main" for more than six months per year, "marginal" for less than six months per year). Given that communities are statutory units in India with a definite boundary and separate land records, the administrative boundaries provided by the Office of the Registrar General & Census Commissioner of India were used.

The use of environmental data has a relatively long tradition within rural development studies due to the fact that rural livelihoods and land use are intertwined (Nguyen et al., 2017; Rigg, 2006; Santiphop et al., 2012a; Watmough et al., 2016). The Geographic Information System QGIS was used to extract different environmental conditions at the community level and to compute euclidian distances to closest resources. Our calculations cover an area extending 100 km beyond the administrative boundary of the study area to avoid edge effects. Land

cover data was used to estimate proxies for environmental conditions. GlobeLand30 data (30 m resolution for 2010) (Chen et al., 2014) and Bhuvan data (25 m resolution for 2011) (NRSC, 2006, 2012) were harmonised using the method developed by Vancutsem et al. (2013) to get a coherent land cover dataset for 2011. The main features extracted from this dataset were built-up (urban/rural), forest cover (evergreen/deciduous/shrubs/mangroves), agricultural land (cropland/plantation/fallow), wasteland, wetland and waterbodies.

4.2.2 Quantification of livelihood capitals

During the rapid rural appraisals, the participants identified the factors that influence their choice of a livelihood activity (see Chapter 3). Proxy variables from the secondary data available described previously were selected to represent the factors identified by the participants. The variables were then assigned to livelihood capitals (natural, physical, human, financial, social) according to the findings from Chapter 3 and the type of good they fall into. Private goods were classified as household capitals and common-pool resources as community capitals. Given the high number of variables falling under each type of capital and their potential collinearity, extraction methods were used to reduce the information to a lower dimensionality space. Principal Component Analysis was used to decrease the amount of redundant information by de-correlating the input vectors, as suggested by Filmer and Pritchett (2001); Vyas and Kumaranayake (2006); Filmer and Scott (2012). Although Filmer and Pritchett (2001) has recommended to use PCA when continuous variables are used and factor analysis when there are both continuous and categorical variables, the weightings for categorical variables derived from factor analysis and PCA are usually very similar (Howe et al., 2008; Watmough et al., 2016). Moreover, PCA has often been used in cases when continuous and categorical variables are used in combination, as it is easier to run and interpret (Howe et al., 2008). It was decided not to combine multiple factors as it would have distorted what the component captured and would have made it difficult to interpret (McKenzie, 2005). The first step consisted in normalising the data stored as a matrix (X) into $\overline{X}$. Then, the eigenvectors (U) and eigenvalues (Λ) of the covariance matrix (C) were calculated using Singular Value Decomposition. Finally, to reduce the dimensionality, the data was projected onto the largest eigenvectors $P = U^T \cdot \overline{X}$. The first eigenvector was kept and checked how the component captured the initial variables. The new vector was kept only if, for each variable, the loading's direction matched the findings from the rapid rural appraisals and if it explained more than 40% of the variance in the data. The index for each capital was then computed by weighting each variable using its factor loading and then summing them.

4.2.2.1 Household capitals

Private assets were grouped together and classified as household livelihood capitals (Table 4.1).

Table 4.1: List of variables used for the quantification of household livelihood capitals. The associated factor loading retrieved from the PCA is shown on the right and represents weight of each variable in the construction of their livelihood capital they fall under.

Category	Variables	Source	Product	Type	Factor
Natural capital					
Rainfed cropland	Non-irrigated area sown per household	Census	VA	Continuous	0.539
Irrigated cropland	Irrigated area sown per household	Census	VA	Continuous	0.255
Tree plantation	Area of tree crops per household	Census	VA	Continuous	0.664
Pasture	Area of pasture per household	Census	VA	Continuous	0.785
Physical capital					
Means of transportation	Proportion of households with access to motorbike	Census	HL	Continuous	0.708
Electricity	Proportion of household with no access to electricity	Census	HL	Continuous	-0.708
Human capital					
Dependency ratio	Ratio of dependent individuals (inactive) per active person	Census	HL	Continuous	-0.725
Illiteracy	Ratio of illiterate individuals per capita	Census	PE	Continuous	-0.725
Financial capital					
Financial services	Ratio of households with access to financial services	Census	HL	Continuous	0.722
Protective assets	Proportion of households without asset ownership	Census	HL	Continuous	-0.777
Housing conditions	Proportion of households with "Dilapidated" houses	Census	HL	Continuous	-0.530
Social capital					
Communication	Proportion of households owning telephone	Census	HL	Continuous	0.718
Castes	Ratio of Scheduled Castes and Tribes	Census	PE	Continuous	-0.718
Marital status	Proportion of households with no married couples	Census	HL	Continuous	-0.456

Measuring household natural capital. A common view amongst participants was that the amount of agricultural land (rainfed and irrigated cropland, tree plantation) available to one household influences their potential income and food, and they considered them as determining factors for their choice of a livelihood activity. Participants in inland communities (C2, C5 and C6) argued that the area of pasture available per household was also a key determinant of employment, as it enabled them to develop livestock rearing as a diversification strategy. The four highest loadings of the eigenvector from the Principal Component Analysis represent these capitals highlighted by participants as determinants for the choice of their livelihood strategy: cropland area per cultivator ($\lambda_{\text{rainfed}} = 0.54$, $\lambda_{\text{irrigated}} = 0.26$), area of pasture per household ($\lambda_{\text{pasture}} = 0.79$) and area of tree plantation per cultivator ($\lambda_{\text{orchards}} = 0.66$). Overall, the first factor loading from the PCA accounted for 67% of the variance in households' access to natural capital and communities which scored high on the first factor were those where households had a greater access to household natural capital.

Measuring household physical capital. A number of factors falling under household physical capital were identified by participants as determinant in their choice of a livelihood strategy. First, private access to electricity enables households to conduct their livelihood activity by operating agricultural pumps and machinery ($\lambda_{\text{no_electricity}} = -0.71$). Means of transportation ($\lambda_{\text{motorcycle}} = 0.71$) also came up during the rapid rural appraisals, since they allow households to look for new outlets for their production or for livelihood opportunities and increase their access to nearby services (hospitals, banks, schools) through the reduction of travel times. The eigenvector kept from the PCA accounted for 49% of the variance in household physical capital.

Measuring household human capital. A recurrent household human capital that was identified by participants as influencing their choice of a livelihood strategy was the number of active members in the household ($\lambda_{\text{dependencyratio}} = -0.73$). A high dependency ratio limits the range of activities that one household can put in place. Finally, level of education and individ-

ual skillsets surfaced in most focus groups (cf. Chapter 3). Participants argued that educated members were a strength for one household because they "did not suffer from unemployment". Based on existing literature about poverty (e.g. Watmough et al., 2016), levels of female illiteracy were used as a negative proxy for this asset ($\lambda_{\text{illiteracy}} = -0.73$). Overall, the eigenvector kept for household human capital accounted for 53% of the variance in household human capital between communities.

Measuring household financial capital. One of the proxies used to quantify household financial capital are households' access to financial services for savings and credits ($\lambda_{\text{financial_services}} = 0.72$). This indicator only captures financial inclusion as defined in the census: only households with access to banking services provided by nationalised banks, private banks, foreign banks and co-operative banks are considered to have access to financial services. However, many smallholder farmers –particularly households from lower castes and the poor– lack access to formal credit and are forced to rely on semi-formal (credit and thrift societies, self-help groups, primary agricultural credit societies) or informal (moneylenders and shopkeepers) sources. Moreover, access to such financial services can become a negative asset when the debt-to-capital ratio is greater than one. Although the unavailability of data to capture such dynamics weakens the explanatory power of this indicator for financial capital, the inclusion of protective assets that are held as a store of value and that can be sold if the household faces an external shock ($\lambda_{\text{no assets}} = -0.78$) enables to proxy households' dependency on informal credit when trying to meet unforeseen expenditure. Participants also identified housing as a measure of the financial capital available to one household, as it is associated with access to financial services. Based on census variables, housing condition was used as a proxy to represent such an asset ($\lambda_{\text{dilapidated}} = -0.53$). The eigenvector kept for household financial capital accounted for 54% of the variance in household financial capital between communities.

Measuring household social capital. Household social capital is about the value of social networks, including bonding with norms of reciprocity. Although not identified clearly as a capital, it emerged from the focus groups that marriage is one of the most important kinship encountered at the household level in rural settings, and so one of the pillar of social capital. Households' marital status was used to represent such kinships ($\lambda_{\text{married_0}} = -0.46$). Evidence from the literature and from participants shows that members from lower castes (scheduled caste and tribes) suffer from social and economic exclusion, from a lack of access to certain types of assets and even from a social unacceptability to undertake some activities. As a consequence, the ratio of SC and ST was considered as a negative proxy for social capital ($\lambda_{\text{caste}} = -0.72$). Finally, participants mentioned that households who owned a mobile phone had stronger social networks, especially outside the village, enabling them to have access to alternative livelihood opportunities ($\lambda_{\text{telephone}} = 0.72$). Overall, the household social capital eigenvector accounted for 41% of the variance in household social capital between communities.

4.2.2.2 Community capitals

After reviewing the determinants of households' livelihood strategies identified by participants (Chapter 3), public and common-pool assets were grouped together and classified as community livelihood capitals (Table 4.2).

Measuring community natural capital. Participants, in particular those from remote communities, argued that the total amount of land in the community was a driver of agricultural livelihoods, as it would increase opportunities for agricultural labour and agricultural marketing. A greater area of cultivated area in the village enables the creation of a supply force that can attract traders to come, as it was the case in the community C10 where an increase in the number of breeding goats households had attracted traders to come, thus creating new livelihood opportunities, such as goat broker. Households who were engaged in non-agricultural activities also argued that the greater the total surface of agricultural land in the village, the more economic activities and livelihood opportunities there are. As a consequence, the area of potential cropland was considered as a positive community capital and included in the quantification of its indicator ($\lambda_{\text{crops}} = 0.72$). Forest resources were unanimously raised by participants as a common-pool capital in communities located near forests. Different products from the forest can be traded, such as timber (wood, charcoal) and non-timber forest products (bamboo, sal seeds, kendu leaves and mahuwa flowers), enabling households to diversify their incomes. As the availability of products in a forest is correlated with its size, such a resource were proxied by the total area of forest accessible to the village, computed from satellite imagery ($\lambda_{\text{forest}} = 0.67$). A number of issues undermining community natural capital in the long-term were also raised by participants, such as the area of land that is left fallow for regeneration ($\lambda_{\text{pressure}} = -0.20$) . Such an area is used by households to diversify their agricultural system: as one participant said about his photo during the *photovoice* activity, "I use non-agricultural land to dry my harvest and other households use it for cow dung preparation". Overall, the eigenvector kept accounted for 48% of the variance in community natural capital between communities.

Measuring community physical capital. The importance of community physical capital to influence the choice of a livelihood strategy recurred throughout the focus groups. Having access to all-weather transportation infrastructures ($\lambda_{\text{road_dist}} = -0.81$) was perceived as a factor that improves working opportunities through access to marketing outlets (traders are able to come to buy goods directly in the community). Although households benefit differently from such assets depending on their wealth and social networks, proximity to a marketing outlet and availability was mentioned as key determinants to develop income-generating activities ($\lambda_{\text{outlet}} = -0.64$). A marketing outlet could be of different types, from general (such as a market) to more specific (such as a cooperative or society), proximity to an outlet acting as a catalyst for activity diversification, such as milk or raw-fish production. Finally, the availability of power supply for agricultural activities in the community ($\lambda_{\text{electricity_agri}} = 0.35$) is a positive community asset enabling households to invest in other means of production (e.g. pumps) without having

Table 4.2: List of variables used for the quantification of community livelihood capitals. The associated factor loading retrieved from the PCA is shown on the right and represents weight of each variable in the construction of their livelihood capital they fall under.

Category	Variables	Source	Product	Type	Factor
Natural capital					
Cropland	Total area of potential cropland in 2010	GL30/Bhuvan	LC	Continuous	0.722
Forest	Total area of forest in 2010	GL30/Bhuvan	LC	Continuous	0.670
Agricultural pressure	Ratio of sown area per unit of potential farmland for 2010	Census/GL30	Authors	Continuous	-0.202
Physical capital					
Power supply	Availability of electricity for agriculture	Census	VA	Dummy	0.351
Accessibility	Distance to nearest concrete road	Census	Authors	Continuous	-0.809
Outlets	Distance to nearest market	Census	Authors	Continuous	-0.642
Human capital					
Medical facilities	Distance to nearest medical facility	Census	Authors	Continuous	-0.842
Educational facilities	Distance to nearest secondary school	Census	Authors	Continuous	-0.847
Water facilities	Distance to nearest drinkable water source	Census	Authors	Continuous	-0.166
Financial capital					
Formal financial institutions	Distance to nearest commercial banks ATM	Census	Authors	Continuous	-0.998
	Distance to nearest cooperative bank	Census	Authors	Continuous	-0.998
Poverty schemes implementation	Distance to nearest public distribution system shop (PDS)	Census	Authors	Continuous	-0.134
Social capital					
Community services	Distance to nearest ASHA	Census	Authors	Continuous	-0.678
	Distance to nearest community centre	Census	Authors	Continuous	-0.615
Recreational facilities	Distance to nearest sports field	Census	Authors	Dummy	-0.677
Women's group facilities	Distance to nearest SHG	Census	Authors	Continuous	-0.691

to buy costly power generators. The eigenvector kept accounted for 56% of the variance in community physical capital between communities.

Measuring community human capital. A number of themes falling under community human capital emerged from the focus groups. Participants argued that proximity to medical, educational and water community amenities would enhance their labour capacity. Availability of education in the premise of the community recurred throughout the discussions, especially during focus groups held with women. They argued that access to schools would enable their children to spend their day there, giving them time for other activities and increasing their future livelihood opportunities. Education scores were computed from the census using Euclidian distance to nearest secondary school ($\lambda_{\text{school}} = -0.85$). Another recurrent theme was the issue of distance to health facilities ($\lambda_{\text{medical}} = -0.84$) and the availability of water infrastructures ($\lambda_{\text{drinkable}} = -0.17$). According to them, a better access to health facilities and to safe water infrastructures would diminish the risk of health problems. Overall, the factor kept for community human capital accounted for 53% of the variance between communities.

Measuring community financial capital. Proximity to a bank was raised as critical when it comes to state schemes and pensions: for example households needed a bank account in order to get paid for work they conducted under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). As a consequence, infrastructures linked to formal financial services were included, such as the distance to the nearest commercial bank ($\lambda_{\text{bank}} = -0.99$) or cooperative banks ($\lambda_{\text{coop}} = -0.99$). Two other types of infrastructures specific to the Odisha context were flagged by participants: the distance to Public Distribution System Shops ($\lambda_{\text{PDS}} = -0.13$), which are shops distributing rations at a subsidised price to the poor. Although PDS are not a financial institution, it was decided to include this variable in the community financial capital because they are a policy financial tool for poverty reduction. The eigenvector kept accounted

for 62% of the variance in community financial capital between communities.

Measuring community social capital. Community social capital emerged discretely from the focus groups, as the concept of social networks at a community level was not identified by participants. However, participants mentioned the importance of social groups such as self-help groups ($\lambda_{SHG} = -0.69$), youth and farmers groups to give them new income opportunities or to increase their migration options. These groups are considered as community-level assets, which enhance social networking that might lead to alternative livelihood opportunities. Participants, and especially women, showed a strong interest in SHGs, which is a way for them to build strong social links and to build their capacities and empower themselves. It also emerged from the discussion that availability of recreation facilities, such as public community spaces ($\lambda_{ASHA} = -0.68$, $\lambda_{comcentre} = -0.62$) or sport fields ($\lambda_{sportfield} = -0.68$) was an important community capital that enabled to build strong kinships and that also prevented younger males to migrate out of the village for work. Overall, the factor kept accounted for 55% of the variance in community social capital between communities.

4.2.3 Methods to analyse associations

The term "association" has been widely used in the literature to analyse different types of compromises between ecosystem services, such as ecological (Vihervaara et al., 2010), temporal (Koch et al., 2009), planning (White et al., 2012) or between beneficiaries (Martín-López et al., 2012). The first classification was developed for the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) and grouped ecosystem services associations into four categories (Rodríguez et al., 2006): (i) associations in space, defined as the spatial lag between production and delivery of a service; (ii) associations in time, defined as the temporal lag in the delivery of a service; (iii) reversibility of ecosystem services, defined as the resilience of a service after a disturbance in its production; and (iv) associations across ecosystem services, defined as the positive or negative effects of the supply of one service on the supply of other services.

To guide the assessment of ecosystem services associations, Mouchet et al. (2014) combined the previous classifications into a new methodological framework by accounting for both ecological and socio-economic aspects of ecosystem services associations. The authors also presented an overview of the quantitative methods available for analysing ecosystem services associations and gave examples of corresponding hypotheses to be tested. To answer this chapter's objective, which was to characterise which livelihood capitals are negatively or positively associated with each others, it was decided to apply this framework to livelihood capitals, although initially built for ecosystem services. Mouchet et al. (2014) argued that the best methods to test such hypotheses were multivariate analyses, when considering more than two services. Moreover, as the indicators built for each livelihood capital were quantitative variables, Principal Component Analysis was chosen as ordinal method for the analysis (Raudsepp-Hearne et al., 2010; Maes et al., 2012; Smart et al., 2010).

4.3 Results

4.3.1 Spatial distribution of livelihood capitals

Autocorrelation analysis showed that all livelihood capitals at both community and household levels, except for community natural and human capitals, were spatially clumped on the landscape rather than randomly distributed ($p < 0.01$, Figures 4.1 & 4.2). Although similarities were found among the spatial patterns of different livelihood capitals (household physical, household human, community physical), most capitals showed distinct individual spatial patterns.

The coastal part of the delta showed a lower household natural capital than the rest of the delta. Household physical, human, financial and community physical capitals were lower in the north eastern part of the delta and in coastal communities, including fishing communities located around the Chilika Lake. Forest-dependent communities, found in the north western part of the delta, had strong natural and human household capitals but low household financial, physical (at both community and household levels) and social (at both community and household levels) capitals.

4.3.2 Associations between livelihood capitals

PCA was used for the analysis of associations between livelihood capitals for both community and household levels (Figure 4.3). The first two components respectively accounted for 55.55% of the total variation in household capitals and 62.28% of the total variation in community capitals. At the household level (Figure 4.3, left), the first principal component accounted for 35.89% of the variation and represented a positive association between access to physical, financial, human and social capitals. The second component accounted for an additional 19.66% and primarily described the segregation of households based on their access to natural resources. At the community level (Figure 4.3, right), the first component accounted for 40.92% of the total variation in community capitals, while the second component accounted for 21.36%. The first principal component showed a negative association between access to natural resources on the one side and access to all other community amenities on the other. The second principal component showed a negative association between access to social amenities on the one side and access to natural resources and financial infrastructures on the other.

A PCA was also computed on all livelihood capitals together, irrespective of their level of analysis (Figure 4.4). The first two components accounted for 38.83% of the total variation in livelihood capitals. The first principal component accounted for 21.03% of the variation and represented a negative association between access to natural resources (at both community and household levels) and community amenities. The second component accounted for an additional 17.8% and primarily described the segregation of household capitals, with natural capital negatively associated with the rest of household-level assets.

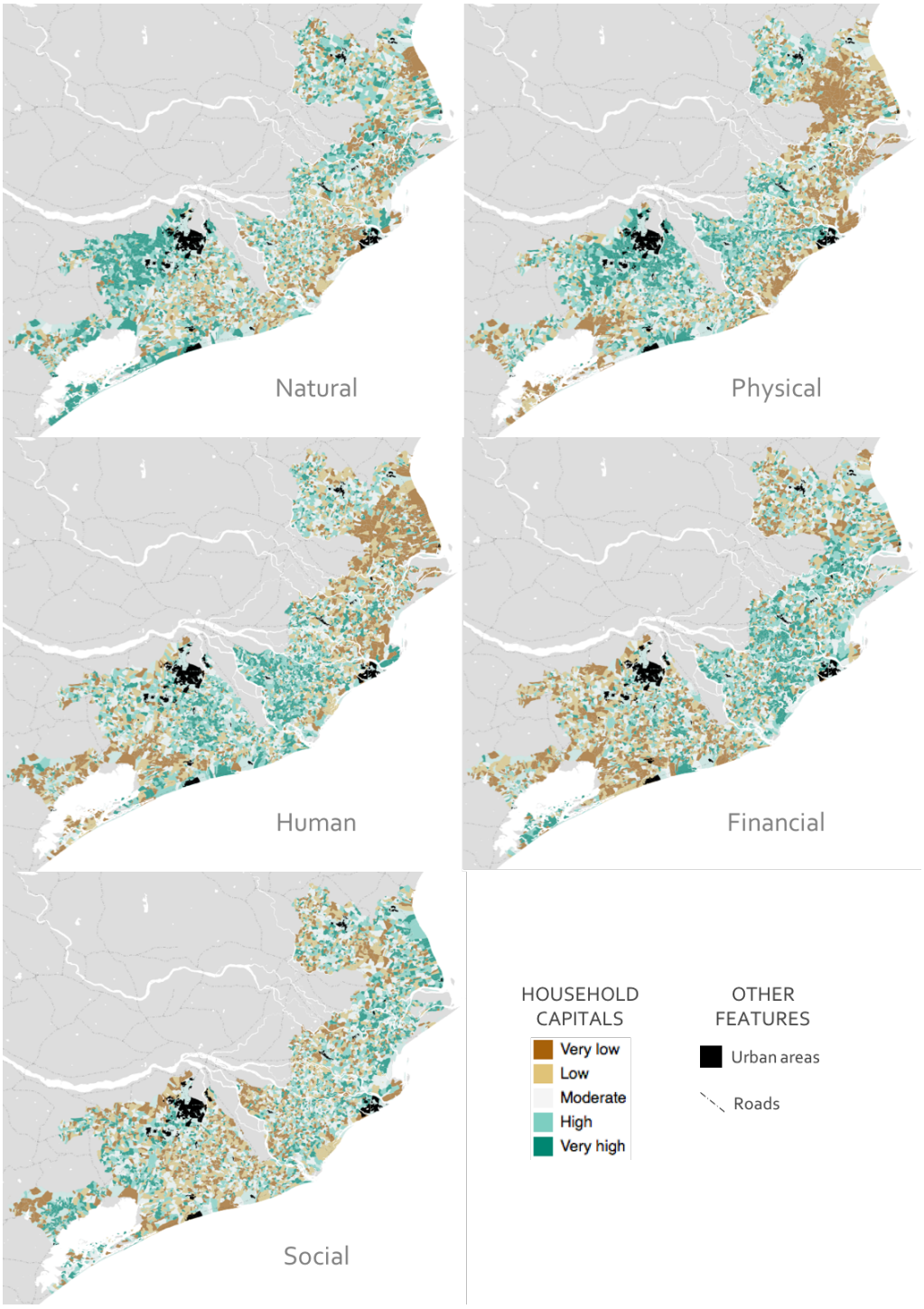


Figure 4.1: Spatial distribution of household capitals in the Mahanadi Delta. Communities were ranked into quintiles based on how they scored for each livelihood capital, from very low (brown) to very high (green).

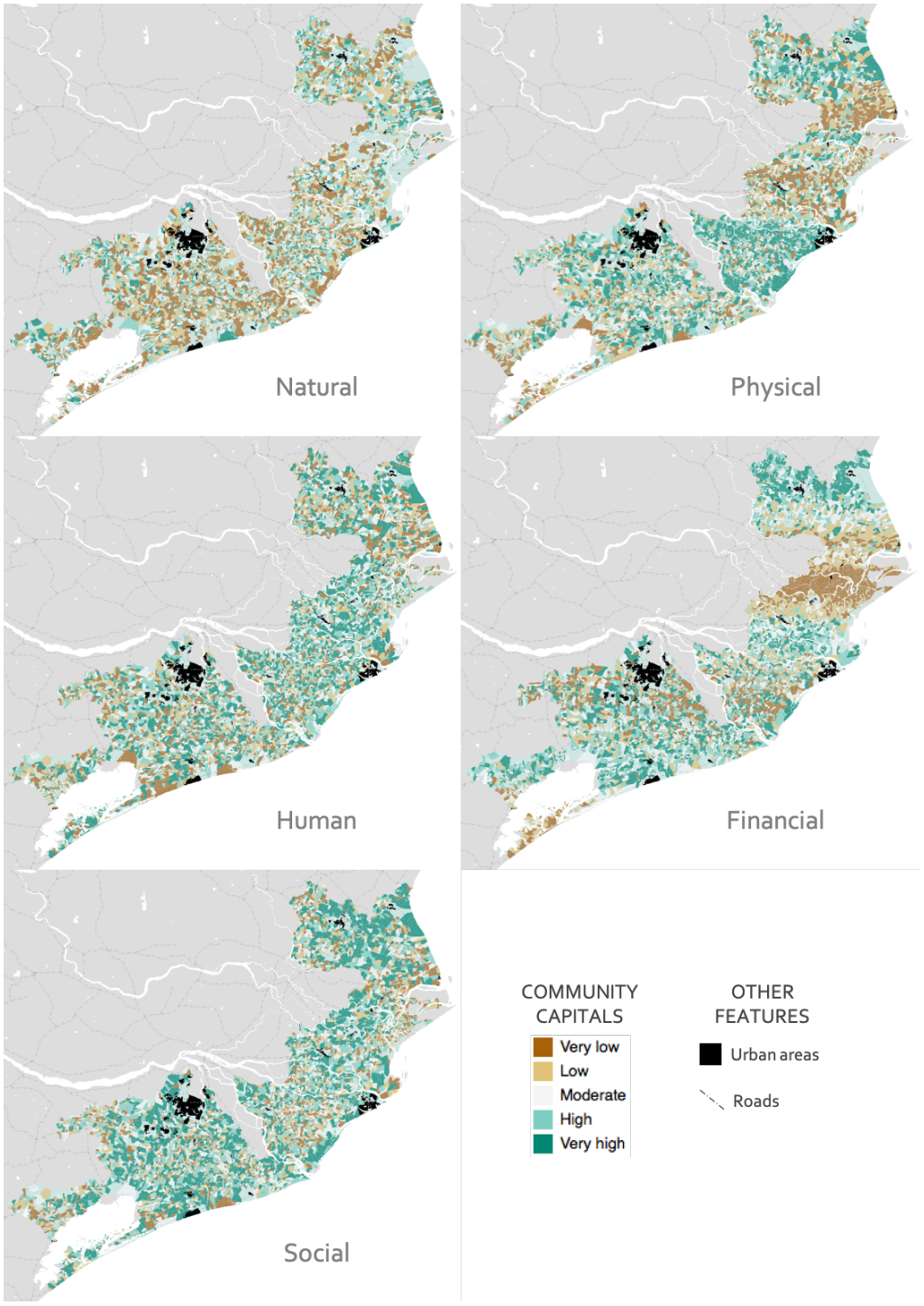


Figure 4.2: Spatial distribution of community capitals in the Mahanadi Delta. Communities were ranked into quintiles based on how they scored for each livelihood capital, from very low (brown) to very high (green).

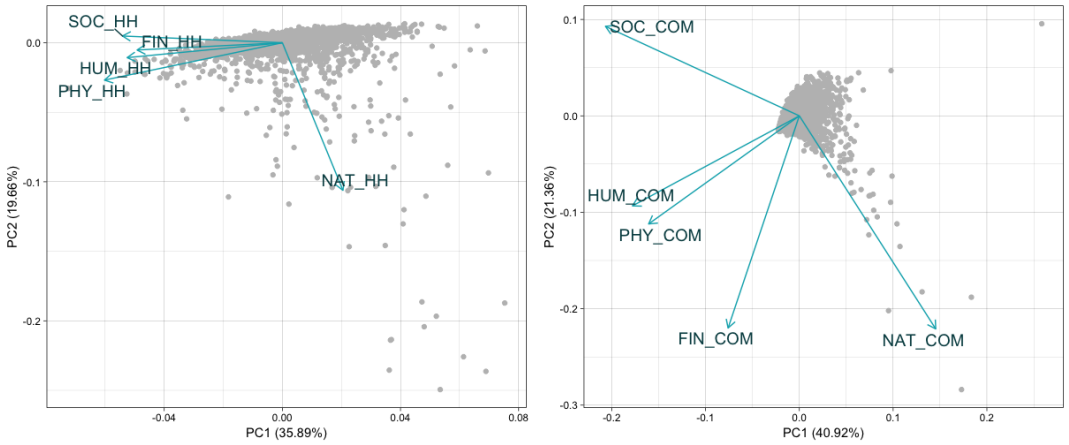


Figure 4.3: Eigenvectors from the PCA on household capitals (left) and on community capitals (right). The two components of the PCA on household capitals show a negative association between natural capital and the four other capitals. The first component of the PCA on community capitals represents a negative association between natural resources and the other types of community amenities. The second component shows that access to natural resources and financial infrastructures is negatively associated with social amenities.

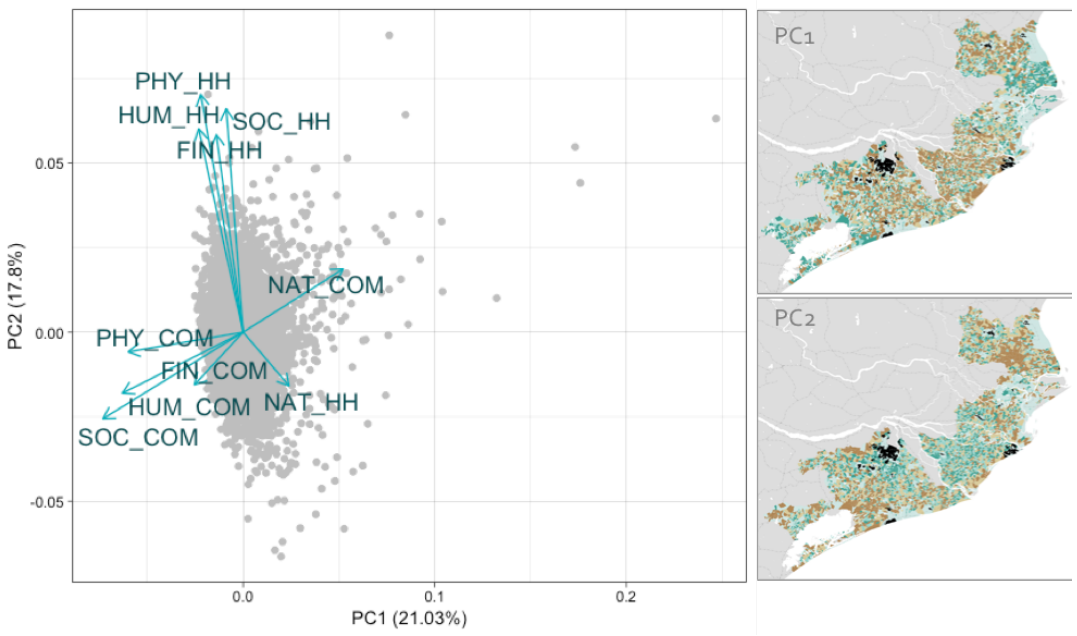
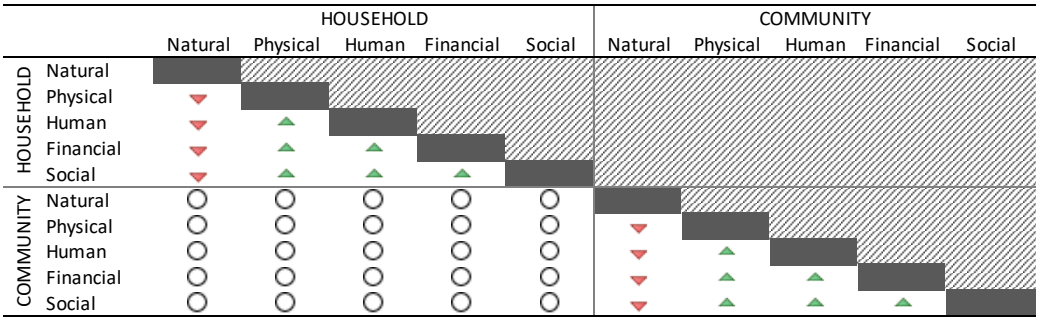


Figure 4.4: Eigenvectors and spatial distribution of the first two components of the PCA on both household and community capitals. The first component (PC1) represents a negative association between natural resources (green) and community amenities (brown). The second component (PC2) represents a negative association between natural capital at the household level on the one side (green) and physical, social, human and financial capitals on the other side (brown).

4.4 Discussion

This chapter presented methods for analysing interactions among livelihood capitals and identified patterns in the spatial distribution of livelihood capitals. It also provided empirical evidence of spatial negative associations between natural and the other capitals at the household level and between natural and social capitals at the community level. Table 4.3 represents a summary of the findings by showing the main associations between livelihood capitals and their spatial patterns.

Table 4.3: Matrix summarising the associations between capitals. Green upward arrows represent positive associations and red downward arrows represent negative associations, while a circle shows that there is no association. Spatial patterns associated with remoteness are shown in the dark cells: 'R' for a livelihood capital associated with remote areas and 'N' for a livelihood capital associated with areas near trading-centres.



4.4.1 Spatial patterns of livelihood capitals

Overall, the findings show that there is a spatial gradient of the distribution of livelihood capitals based on proximity to the main trading axes (map PC1, Figure 4.4). Households have better physical access to community amenities but a lower access to common-pool natural resources (lakes, forests) when they are located close to main trading-centres or main roads. The second spatial gradient (map PC2, Figure 4.4) shows that household natural capitals increases with remoteness, while household physical and financial capitals increase with proximity to main roads. In other terms, although proximity to trading centres and community amenities is associated with an increase in households' access to productive (physical) and protective (financial) assets, it is most of the time accompanied by a loss in access to natural resources for the household. It can thus be suggested that opportunities created by the proximity to trading centres and a greater access to financial services is likely to be associated with dynamics of land-grabbing (Chapter 2), resulting in a temporary or permanent loss of household natural capital.

The findings for household natural capital corroborate the results of Gumma et al. (2014) who presented a new land cover classification accounting for the different types of agricultural systems found in the delta. Notably, communities with low natural capital are clustered in the coastal part of the delta and seem to be associated with irrigated double cropping, while

communities with high natural capital are located near forested areas, where rainfed mixed agricultural systems are prevailing. These results are likely to be related to how the indicator for natural capital is built, in which only farm size is taken into account and not production. Irrigated farms where two or three crops per year are grown require more labour per surface unit, thus these farms are smaller on average (Directorate of Agriculture & Food Production Odisha, 2014), which leads to lower scores of natural capital (but greater scores of physical capital). On the contrary, rainfed mixed-agricultural systems are more extensive and require bigger farms for a similar production, leading to higher scores of household natural capital.

Although the signal for community physical capital is weaker than the one for household physical capital, their spatial distribution present a similar pattern with lower scores in coastal communities and in the north-eastern part of the delta. Communities located in these remote areas do not have access to irrigation facilities and have a limited access to electricity and to markets. This result echoes the findings of Chhotray and Few (2012); Bahinipati (2014) who highlighted the remoteness of these areas and that households lacked access to physical amenities, partly as a consequence of natural hazards such as the Odisha super-cyclone in 1999.

The distribution of the community human capital suggests that there is a relative homogeneous access to primary health facilities across the delta. However, households located in the south-western and north-eastern parts of the delta have a lower access to household human capital. These findings mirror the findings from Chapter 3 and of DECCMA (2017), which showed that the districts of Kendrapara and Bhadrak had the highest levels of male migration. Rural-urban male migration leads to an increase in the number of left-behind wives and to a decrease in households' labour force, thus leads to households with a lower household human capital (Agasty and Author, 2014; Velan and Mohanty, 2015; Parida, 2016).

Similarly to the spatial distribution of communities with a low household physical capital, communities with a low household financial capital are located in the fringe of the lake Chilika and in the north-eastern part of the delta. This is mainly due to the lack of ownership of protective equipment and the high number of "dilapidated houses" stemming from the impact of natural hazards. Contrary to expectations, the findings show that community financial capital is not directly linked to accessibility, which can be explained by the omnipresence of Primary Agricultural Credit Society in agricultural communities, even in the most remote areas (Kamath et al., 2010). However, the presence of financial institutions within a community does not guarantee households to have access to financial services (Imai et al., 2010), as demonstrated by their perpendicular eigenvectors (Figure 4.4).

The spatial distribution of community social capital shows that this indicator is associated with accessibility, which is consistent with the absence of recreational facilities in remote communities. On the other hand, household social capital seems to be lower near natural areas such as forests (south-west and near the mangroves in the north-east) and open water (near the Chilika lake and along the coastline), which corroborates the finding of De Haan and Dubey (2005).

4.4.2 Interactions between livelihood capitals

Altogether, the findings highlighted three distinct positive associations between livelihood capitals and two main negative associations (Figure 4.4). Physical, financial and human capitals are positively associated at the community level, which corroborates the fact that community amenities are usually grouped together and located in large or medium-size towns. Overall, these associations demonstrate a strong negative association between access to community amenities on the one side and access to natural resources on the other, which supports previous research on ecosystem services in Canada (Raudsepp-Hearne et al., 2010), Denmark (Turner et al., 2014) and Sweden (Queiroz et al., 2015).

At the household level, the findings show that physical capital is positively associated with financial, human and social capitals. This finding supports the results from Chapter 3, which showed that wealthy households who own means of transportation would also own protective assets, would invest in their house and would have a better access to financial services. Moreover, participants also mentioned that non-married households (widowed, divorced, single) and households from scheduled castes would very rarely own productive or protective assets because of the social barriers they face (see Chapter 3), which corroborates the association between social capital and both financial and physical capitals found in the present chapter. This bundle is negatively associated with household natural capital, which represents households' access to agricultural land. Based on the fieldwork, it seems possible that this negative association represents a proxy of coping dynamics: poor households sell part of their land (natural capital) to cope with shocks and increase their income (financial capital), which is then invested in their physical and human capitals, as observed by Parida (2016).

4.5 Conclusion

This chapter presented an innovative way of integrating findings from participatory fieldwork with national census and environmental data to characterise associations between livelihood capitals. More specifically, this is the first time that a study quantified spatial associations between livelihood capitals. The existence of a negative association between access to community amenities on the one side and access to natural resources on the other was clearly supported by the findings. Moreover, the results suggest that household physical capital is positively associated with household financial and social capitals but negatively associated with household natural capital, supporting the findings from Chapter 3, which showed that the poorest households sell part of their agricultural land to face agricultural shocks and to increase their income. It was also shown that proximity to main axes of communication is positively associated with access to community amenities but negatively associated with access to natural resources, while remoteness is positively associated with household natural capital but negatively associated with household physical and human capitals.

Overall, this chapter demonstrates that there are associations between livelihood capitals and

that they are spatially clustered, which gives new insights for rural planning. However, further work needs to be conducted to explore the role livelihood capitals play in the choice of livelihood strategies. Characterising the influence of livelihood capitals on livelihood activities is essential to understand the determinants of rural poverty, which is the aim of the next analysis chapter.

CHAPTER 5 Influence of household and community capitals on agricultural livelihoods

Following on from the quantification of household and community capitals, this chapter characterises their associations with agricultural livelihood activities by using national census data in a multilevel modelling framework. Building on the previous chapters, it shows that apart from power relationships of class and caste, community resources and household capitals also have an effect on driving precarious agricultural livelihoods. A lack of access to physical, human, financial and social capitals at the household level is associated with vulnerable activities, such as daily-wage agricultural labour. Communities with a greater access to community natural capital are associated with less agricultural labour. This chapter also shows that proximity to rural centres and access to financial infrastructures are associated with greater chances of agricultural households engaging in precarious activities such as landless agricultural labour. These findings suggest that investments in rural infrastructure might increase livelihood vulnerability if they are not accompanied by an improvement in the provisioning of complementary rural services such as access to rural finance and by the implementation of agricultural tenancy laws to protect smallholders' productive assets.

Results from this chapter were presented at the Tropmet conference "Climate Change and Coastal Vulnerability" in Bhubaneswar (India), December 2016, at the ESRC conference "Innovation" in Southampton (UK), December 2017 and at the FAO Expert Workshop on Socio-ecological Systems in Rome (Italy), January 2018.

5.1 Introduction

Despite the Government of India's efforts to eradicate poverty, statistics show that the percentage of agricultural workers in India who are cultivators has declined from 72% to 45% between 1951 and 2011, whilst the percentage of landless agricultural labourers has increased from 28% to 55% (Indian Ministry of Labour and Employment, 2015). This considerable rise in landless agricultural labourers is an indication of growing rural poverty. Geographically, wide variations exist both within and between rural communities, with chronic indebtedness and poverty being highest in communities dominated by agricultural labourers. Building on the extensive literature that has looked at the determinants of agricultural employment from caste and class perspective, this research integrates a territorial approach to characterise if there are significant household and community determinants of precarious livelihoods that could enrich our understanding of the drivers of rural poverty in India. In this regard, characterising the influence of both access to privately owned assets and to public goods on the susceptibility of communities to landless agricultural labour could contribute to the enactment of policies targeting marginalised and vulnerable households. Incorporating local knowledge in the Sustainable Livelihood Framework (SLF), which has been used extensively to examine the associative relationships between access to capitals and poverty (see Chapter 2), this chapter aims to examine the collective associative effects of access to household and community capitals (classified into natural, physical, human, financial and social) on the susceptibility of households to engage in landless agricultural labour in the Mahanadi Delta. This chapter shows the differential impacts of household and community capitals on the dynamics of poverty and builds on Chapter 4 to demonstrate how local knowledge augments a quantitative use of the SLF. Moreover, this research statistically demonstrates the relevance of integrating a multilevel perspective to the SLF to characterise the determinants of rural livelihoods, which can be replicated in different geographic settings in low and middle-income countries.

As seen in Chapters 1 and 2, the Mahanadi Delta in the Odisha State of India is one of the populous deltas where environmental stressors have adversely impacted livelihood opportunities, exacerbating poverty levels and driving households into chronic poverty (Chhotray and Few, 2012; Das, 2012; Dhamija and Bhide, 2013). Subsistence agriculture remains the main source of livelihood for most of the delta's population, with 68% of the population dependent on agriculture for their livelihoods (Registrar General and Census Commissioner, 2011; Samal et al., 2006). The India Population and Housing Census classifies agricultural workers into cultivators and agricultural labourers. Cultivators cultivate on their own land or land held by the Government, private persons or institutions for payment in money, kind or share. Agricultural labourers, on the other hand, work on other peoples' land for wages and have no right of lease or contract on land (Datta et al., 2015). These landless agricultural labourers are amongst the most exploited and are often trapped in a vicious cycle of indebtedness and chronic poverty (Mosse et al., 2002; Das, 2012; Ravi and Engler, 2015).

The problem of landless agricultural labour in the Mahanadi Delta has been compounded by high population density (623 inhabitants per square kilometre) and recurrent environmental

disasters including cyclones, erosion, storm surges, floods and droughts (Bahinipati, 2014; Ericson et al., 2006; Syvitski, 2008), resulting in the loss of agricultural land, intensification of farming systems and persistent crop failures (Dixon et al., 2001; Savath et al., 2014b). The continual rise in landless agricultural labourers has been attributed to households' inability to cope with the impacts of environmental shocks (see Chapter 3). Following a crop failure, agricultural households have to sell off their agricultural land to manage the immediate impacts or are unable to fulfil their lease obligations (Christiaensen et al., 2011; Hall et al., 2015; Singh, 2002). Working members of these households often become unemployed with limited livelihood opportunities to move out of poverty, but either to migrate or become agricultural labourers (Mosse et al., 2002; Ravi and Engler, 2015; Williams et al., 2016). Detailed examinations of poverty structures in rural India show that households engaged in agricultural labour are the poorest of the rural poor (Himanshu et al., 2013; Ravi and Engler, 2015). In particular, agricultural labour is seen as a demeaning work, which provides very low wages compared to other types of daily wage employment (Himanshu et al., 2013).

Employment opportunities available to rural households in low and middle income countries are highly dependent on their access to private assets (household capitals) but also to the common-pool resources they have access to (community capitals), which contributes to their resilience to social, economic and environmental stresses (Adger et al., 2002). While livelihood perspectives have provided a holistic approach to understand the systems in which rural poverty exists, most of them only consider household-level assets and capabilities as determinant for households' employment opportunities, and have been criticised for their lack of operationalisation at multiple spatial scales (Reed et al., 2013). However, community-level assets, such as access to communal natural resources (forest, lakes) and distance to services (markets, hospitals) are a significant component of rural livelihoods and poverty (Palmer-Jones and Sen, 2006) and have an influence on households' economic opportunities (Okwi et al., 2007). Chapters 3 and 4 showed that community-level assets have an influence on households' choice of a set of livelihood activities. Although conceptual studies have mentioned the importance of differentiating community capitals from household capitals (Lindenberg, 2002; Gutierrez-Montes et al., 2009), the livelihood studies that have dealt with community-level assets did not yet explore their role on agricultural employment (e.g. Hahn et al., 2009; Donohue and Biggs, 2015). In this chapter, local knowledge presented in Chapter 3 combined with indicators of household and community capitals derived from the methods presented in Chapter 4 are used to examine the susceptibility of communities to landless agricultural labour, which is an indicator of chronic poverty (Objective 2).

5.2 Methods

The analysis was conducted at the community (village and ward) level, which is the lowest geographical disaggregation and local government administrative unit in India. India operates a five-tier local government administrative system, consisting of States (29) and Union Territories (7), which are subdivided into Districts (696). Districts are partitioned into Tehsils, which are

further classified into Gram Panchayat, which are divided into communities (villages and wards) (Registrar General and Census Commissioner, 2011). Communities with a population lower than ten and with less than 20% of the active population engaged in agricultural activities were removed from the data to prevent small size effects (Coe, 2002). In total, the analysis covered 3,620 rural communities in five (Bhadrak, Jagatsinghapur, Kendrapara, Khordha and Puri) districts in the Mahanadi Delta of the Odisha State.

5.2.1 Quantifying household and community capitals

Based on Chapters 3 and 4, a multidimensional matrix of indicators was identified to quantify each of the household and community capitals. The variables used for the construction of household and community capitals in this chapter differ slightly from the ones used in Chapter 4, in which all variables mentioned by the participants were proxied and included. However, in order to use these indicators into a significant statistical analysis for this chapter, they had to capture the maximum variation possible and thus only a few important variables were be kept in the construction of the indicator (Jones and Andrey, 2007; Howe et al., 2008; Moser and Felton, 2009).

A principal component analysis technique was then used to derive a single factor score for each capital, ensuring that the factor loadings correspond with the conceptualisation of each capital based on the participatory activities. Given the high correlation amongst the selected variables, principal component analysis was used to circumvent the problem of multi-collinearity (Amoako Johnson and Hutton, 2012). Multiple factors were not combined as this would have distorted what the component captured and would have made it difficult to interpret (McKenzie, 2005). The first factor score was selected to represent each capital and categorised into quintiles to show the communities with least access to each capital and those with the highest access.

5.2.2 Statistical modelling of the effects of household and community capitals on agricultural labour

Multilevel logistic regression techniques were used to investigate the associative effects of household and community capitals on the odds of being an agricultural labourer. The response variables are the proportion of the population aged 15-59 in a community that are: (i) agricultural labourers, derived as the ratio of agricultural labourers to total population engaged in agricultural activities; and (ii) marginal agricultural labourer, computed as the ratio of agricultural labourers who work less than six months per year to the total agricultural labour population.

The proportions of the response variables of interest vary continuously over the range of 0 and 1. Thus, fitting a linear regression model to this data risks predicting invalid values outside the range of 0 and 1. In this regard, a Generalised Linear Mixed (GLM) model with a logit link was adopted, specifying the total number of adults who are engaged in agricultural activities as the

denominator, to ensure that predicted values remain in the range of 0 and 1 (Rasbash et al., 2005). Three-level GLM models were fitted with 3,620 rural communities (level 1) nested in 2,420 Gram Panchayat (level 2), further nested in 67 Tehsils (level 3).

A sequential model-building process was used to examine the extent to which the household and community capitals explain the odds of being an agricultural labourer, accounting for important confounders. To identify the true effects of household and community capitals, the models accounted for the confounders (districts to which the communities belong, population density of the communities) and random effects (Lyle, 2015). Participants from disadvantaged socio-economic classes argued that scheduled caste (SC) and tribe (ST) members suffer from social and economic exclusion, from a lack of access to certain types of assets and even from a social unacceptability to undertake some activities. As a consequence, we controlled for the ratio of scheduled castes and tribes in the different models to capture the true effects of household and community capitals. Model 2 added the household capitals, whilst Model 3 further added the community capitals. The models were fitted using MLwiN 3.01 (Charlton et al., 2017; Rasbash et al., 2005). A Bayesian modelling approximation method was used to estimate the model parameters (Browne et al., 2014). This approach uses a combination of two Monte Carlo Markov Chain (MCMC) procedures, Gibbs sampling and Metropolis-Hastings sampling, to generate a large number of simulated random draws from the joint posterior distribution of all the parameters. It then uses these random draws to form a univariate summary of the underlying distributions, which is useful for producing accurate interval estimates.

5.3 Data and Materials

The indicators to quantify the capitals in this chapter were based on the ones indicated by participants during the rapid rural appraisals (Chapter 3) and included a reduced number of demographic, infrastructure, amenities, and environmental indicators compared to Chapter 4, as discussed previously (Tables 5.1 and 5.2). The data used for the analysis were derived from the 2011 India Population and Housing Census and 2011 Bhuvan satellite imagery. The Census and remotely sensed satellite sensor data were adopted because they provide detailed data at a higher spatial resolution (community) and are publicly accessible online.

The demographic, infrastructure and amenities data used in the analysis were derived from the 2011 India Population and Housing Census (Registrar General and Census Commissioner, 2011). The census indicators comprise population enumeration including cultivators (marginal and main), agricultural labourers and entrepreneurs (marginal and main), education, literacy, mean income and expenditure, access to health facilities, drinking water, communication, banking, recreational and cultural facilities, power supply and natural resources. Only one livelihood activity is recorded per person and is classified as main (work for more than six months) or marginal (work for less than six months).

The use of environmental data has a relatively long tradition within rural development studies due to the fact that rural livelihoods and land use are intertwined (Nguyen et al., 2017; Rigg,

Table 5.1: List of variables used for the quantification of household livelihood capitals. The associated factor loading retrieved from the PCA represents the weight of each variable in the construction of each livelihood capital.

Category	Variables	Source	Weight	Justification from participatory rural appraisals
NATURAL CAPITAL				
Cropland	Average area sown per cultivator	Census	0.382	Influences households' incomes and food security.
Tree plantation	Average area of tree crops per cultivator	Census	0.398	Enables households to generate extra incomes.
Pasture	Average area of pasture per cultivator	Census	0.440	Enables households to develop livestock rearing.
PHYSICAL CAPITAL				
Electricity	No access to electricity (%)	Census	−0.083	Lack of electricity prevents households to conduct their livelihood activity (to operate agricultural pumps and machinery).
Means of transportation	Access to bicycle (%)	Census	0.445	Enables households to look for new outlets for their production and increase their access to nearby social services through the reduction of travel times.
	Access to motorcycle (%)	Census	0.530	
	Access to car (%)	Census	0.400	
HUMAN CAPITAL				
Dependency ratio	Number of inactive per active person	Census	−0.687	High dependency limits the range of activities that the household can put in place and reduces investment.
Illiteracy	Illiterate individuals (%)	Census	−0.687	Educated members were a strength for one household because they "did not suffer from unemployment".
FINANCIAL CAPITAL				
Financial services	Access to financial services (%)	Census	0.682	Enables households to invest in their other capitals and develop their livelihood opportunities.
Housing conditions	"Dilapidated" houses (%)	Census	−0.682	Value and condition of housing represents the financial condition of households.
SOCIAL CAPITAL				
Marital status	No married couples (%)	Census	−0.395	Marriage is one of the most important kinship encountered at the household level in rural settings.
Mobile phone	Ownership of mobile phone (%)	Census	0.569	Mobile phones enable households to communicate with migrants and strengthen networks.

Table 5.2: List of variables used for the quantification of community livelihood capitals. The associated factor loading retrieved from the PCA represents the weight of each variable in the construction of each livelihood capital.

Category	Variables	Source	Weight	Justification from participatory rural appraisals
NATURAL CAPITAL				
Cropland	Total cropland area	GL30	0.650	Greater amount of land in the community increases opportunities for agricultural livelihoods.
Forest	Total area of forest in the community	GL30	0.198	Access to forest can provide extra income, food and energy supply.
Open-water	Travel time to aquaculture areas	OSM	−0.589	Access to open-water resources can provide extra income and food supply.
Irrigation	Proportion of cropland with irrigation	Census	0.343	Public irrigation infrastructures enable farmers to grow multiple crops a year.
PHYSICAL CAPITAL				
Markets	Travel time to closest market	Census	−0.534	Proximity to markets enable farmers to sell their products and to look for alternative livelihoods.
Industry	Travel time to closest industrial zone	OSM	−0.534	Proximity to industrial areas increases households' opportunities for alternative livelihoods.
HUMAN CAPITAL				
Health facilities	Travel time to closest hospital	Census	−0.704	Proximity to hospitals enables households to cope more rapidly with shocks on their labour force.
Schools	Travel time to closest secondary school	Census	−0.704	Proximity to schools increases the capacity of youth members of the household.
FINANCIAL CAPITAL				
Banks	Travel time to closest bank	Census	−0.582	Proximity to banks enables households to get financial services and access to national poverty schemes.
ATM	Travel time to closest ATM	Census	−0.408	ATMs enable households to get access to cash and was seen as important for livelihood opportunities.
Public Distribution System	Travel time to closest PDS centre	Census	−0.689	Proximity to PDS enables the poorest households to get access to national poverty schemes.
SOCIAL CAPITAL				
Community centre	Travel time to closest community centre	Census	−0.341	Community centres are key amenities for socialisation in rural areas.
Recreation	Travel time to closest sport field	Census	−0.677	Recreational infrastructures prevent youth to migrate and is a lever to find livelihood opportunities.
Union	Travel time to closest Self-Help Group	Census	−0.319	Self-Help Groups are powerful networking institutions that can provide livelihood opportunities.

2006; Santiphop et al., 2012b; Watmough et al., 2016). The Geographic Information System software QGIS was used to extract different environmental indicators at the community level and also to compute travel times to closest resources. The calculations cover an area extending 100 km beyond the administrative boundary of the study area to avoid edge effects. The main features extracted from the Bhuvan land cover dataset (25 m resolution for 2011) (NRSC, 2012)

are built-up area, forest cover (evergreen/deciduous/shrubs/mangroves), agricultural land (cropland/plantation/fallow) and waterbodies.

5.4 Results

5.4.1 Results from the Rapid Rural Appraisals

As seen in Chapter 3, local residents and stakeholders identified key factors, which impact their livelihood opportunities. These were grouped into different capitals based on the SLF. Private assets were classified as household livelihood capitals whilst public and common-pool assets were classified as community capitals. The capitals were further categorised into natural, physical, human, financial and social capitals based upon the views of the stakeholders and local residents. The following section provides a reminder of the main capitals highlighted and their associations with livelihood activities. It provides a necessary summary of the context and background for the statistical analysis as to which capitals are determinant for livelihood opportunities.

5.4.1.1 Household livelihood capitals

A common view amongst stakeholders and local residents was that access to cropland and pasture influences households' livelihood opportunities. Households with a greater area of these assets are able to raise incomes required to acquire land, boost their income generating potentials and access to food. Participants in communities located near forests (communities C9 and C10, Figure 3.1) emphasised the importance of the area of tree crops per household for their income and energy supply, while participants in inland communities (C2, C5 and C6, Figure 3.1) argued that the area of pasture available per household was a key determinant of employment, as it enabled them to develop livestock rearing as a diversification strategy.

Several factors falling under household physical capital were identified by participants as determinant in their choice of a livelihood strategy. First, access to electricity enables households to conduct their livelihood activity by operating agricultural pumps and machinery. Means of transportation also surfaced during rapid rural appraisals as they allow households to look for new outlets for their production and increase their access to nearby services (hospitals, banks, schools) through the reduction of travel times.

A recurrent household human capital identified by participants as influencing their livelihood opportunities was the ratio between active and inactive members in the household, as a high dependency ratio limits the range of activities that the household can put in place. The level of education and individual skillsets also surfaced in most discussions. Participants argued that educated members were a strength for one household because they "did not suffer from unemployment".

Household financial capital includes households' access to financial services for savings and credits and any protective asset that is held as a store of value and that can be sold if the household faces an external shock. Participants identified housing as an important store of value and was according to them the principal indicator of one household's access to financial capital.

Household social capital encompasses the value of social networks, including bonding with norms of reciprocity. Although not identified clearly as a capital, it emerged from the focus groups that marriage is one of the most important forms of kinship encountered at the household level in rural settings and, thus, one of the pillars of social capital. Finally, participants mentioned that households who owned a mobile phone had stronger social networks, especially outside the village, enabling them to have access to alternative livelihood opportunities.

5.4.1.2 Community livelihood capitals

Participants argued that the total amount of land in the community was a driver of livelihood opportunities, as it would increase synergies for agricultural marketing and for agricultural labour. All participants emphasised the importance of forest within the premises of the community for livelihood diversification, extra income and energy supply. Community non-agricultural land was also identified as an asset for livelihood opportunities: as one participant said, "I use non-agricultural land to dry my harvest and other households use it for cow dung preparation". Proximity to water resources or community ponds was unanimously flagged by participants as a source for alternative livelihoods and extra incomes through aquaculture. Finally, the availability of irrigation infrastructures in the community was mentioned as a determinant public good that enabled them to increase their income. Moreover, participants identified that households located in communities who had access to this infrastructure were more likely to remain as a cultivator as it reduces the risks of crop failures due to droughts and floods.

The key ability of community physical capital to influence the choice of a livelihood strategy recurred throughout the focus groups. Three broad themes emerged from the discussions. Accessibility of the community through road infrastructures and distance to market outlets were identified as key physical determinants of livelihood strategies. The last theme was the proximity to industries, as they were providing households with more salaried livelihood opportunities or long-term marketing outlets for their agricultural production.

Several themes falling under community human capital emerged from the focus groups. The availability of education facilities in the premises of the community recurred throughout the discussions, especially during focus groups held with women. Another recurrent theme was the issue of distance to health facilities, which prevented households to cope with shocks on their labour force, such as illnesses or injuries.

Community financial capital includes infrastructure linked to financial services, such as the availability of commercial or cooperative banks, the availability of agricultural credit societies or proximity to an ATM. One other type of infrastructure specific to the Indian context was also

flagged by participants: the availability of Public Distribution System Shops (PDS), which are shops distributing rations at a subsidised price to the poor. Although PDS are not a financial institution, it was decided to include this variable in the community financial capital because they are a policy financial tool for poverty reduction and were mentioned as a financial asset by participants.

Community social capital emerged discretely from the focus groups, as the concept of social networks at a community level was not identified by participants. Young interviewees argued that the availability of recreational infrastructure, such as sport fields, was important to them and was a driver of outward migration in their absence, while women unanimously described the availability of a community centre and of Self-Help Groups (SHG), which are village-based financial unions developing income-generating activities, as determinant social institutions for their livelihood opportunities.

5.4.1.3 Vulnerable livelihood activities

Three groups of livelihood activities, which can be linked to their degree of vulnerability to external shocks, from lowest to highest: (i) off-farm salaried employment, which ensures regular income and mostly consists of public employment (government, administration, teachers) and private services (bus drivers, cooks, construction workers); (ii) self-employment, such as cultivation (farmers who own their land) and off-farm business activities (retailers, wholesalers, equipment owners, bus operators, private entrepreneurs and other service providers), and which provides households with above-average income although it does not guarantee a regular wage; and (iii) temporary employment or daily-wage labour, such as agricultural labour, construction work and junk collection, amongst others, which does not give any guarantee to the household. Participants confirmed that the most vulnerable type of livelihood was agricultural labour, amongst which marginal agricultural labourers were the poorest.

5.4.2 Multilevel Logistic Model for Agricultural Labour

Three different models were fitted to analyse the effects of the different explanatory variables on agricultural labour (Table 5.3). The lowest Deviance Information Criterion is obtained when both community and household capitals are included in the model (Model 3, DIC decreased by 16,354 compared to Model 1 and by 1,105 compared to Model 2). The large decline in the DIC shows that both types of capitals are required in the model, thus, indicating that Model 3 is the model that explains the most variation in the proportion of agricultural labourers.

Model 3 shows that communities located in the Districts Khordha and Jagatsinghpur have higher odds of being agricultural labourer when compared to those in Puri ($OR_{Khordha}$ = 1.27, 95% CI = 1.08, 1.51; $OR_{Jagatsinghpur}$ = 1.43, 95% CI = 1.15, 1.79). There is also a significant negative effect of population density on the odds of being agricultural labourer (OR = 0.58, 95% CI = 0.56,

0.60). Moreover, belonging to disadvantaged groups (scheduled castes and tribes) increase the odds of being agricultural labourer (OR = 3.66, 95% CI = 3.44, 3.89).

Concerning the associations between household capitals and agricultural labour, the results obtained from Model 3 show that the five capitals have a statistically significant effect on the odds of being agricultural labourer. Agricultural households with very low access to human capital are more likely to be agricultural labourers when compared to those with very high human capital ($OR_{Very\ Low}$ = 1.52, 95% CI = 1.46, 1.58). It is also apparent that a lower access to financial ($OR_{Very\ Low}$ = 1.22, 95% CI = 1.18, 1.27) and social capital ($OR_{Very\ Low}$ = 1.16, 95% CI = 1.12, 1.19) increases the odds of being an agricultural labourer compared to cultivator. The odds of being an agricultural labourer are also significantly higher for households with very low household physical capital ($OR_{Very\ Low}$ = 1.28, 95% CI = 1.23, 1.33) when compared to households with very high household physical capital. Regarding household natural capital, a very low ($OR_{Very\ Low}$ = 0.11, 95% CI = 0.11, 0.12) access to this capital decreases the odds of engaging in agricultural labour when compared to households with very high household natural capital.

As Table 5.3 shows, community natural, physical and human capital have a significant effect on the odds to be an agricultural labourer compared to cultivator. Actually, households with a very low access to community natural ($OR_{Very\ Low}$ = 1.25, 95% CI = 1.20, 1.29), physical ($OR_{Very\ Low}$ = 1.12, 95% CI = 1.09, 1.16) or human ($OR_{Very\ Low}$ = 1.15, 95% CI = 1.12, 1.19) have higher odds of being agricultural labourer than households with a very high access to them On the contrary, the odds of being agricultural labourer decrease with lower access to community financial capital ($OR_{Very\ Low}$ = 0.76, 95% CI = 0.73, 0.79). Similarly, the odds of being agricultural labourer decrease for households with lower community social capital ($OR_{Very\ Low}$ = 0.80, 95% CI = 0.77, 0.83).

5.4.3 Multilevel Logistic Model for Marginal Agricultural Labour

Three models were fitted to analyse the effects of community and household livelihood capitals on the odds of being a marginal agricultural labourer (working for less than six months) compared to main (working for more than 6 months). The results obtained from the different models are summarised in Table 5.4. The lowest DIC was obtained by adding both household and community capitals to the model (Model 3, DIC decreased by 4,712 compared to Model 1 and by 595 compared to Model 2), indicating that this model explains the most variation in the proportion of marginal agricultural labourers.

It is apparent from Model 3 that the likelihood of being a marginal agricultural labourer is not influenced by the district in which households are located. Similarly, the model shows that population density does not have a significant effect on the odds of being a marginal agricultural labour. On the contrary, people belonging to disadvantaged groups (scheduled castes and tribes) have higher odds of being agricultural labourer (OR = 2.87, 95% CI = 2.68, 3.08).

Agricultural labourers who have a very low access to household physical ($OR_{Very\ Low}$ = 1.33,

95% CI = 1.26, 1.40), human ($OR_{Very\ Low}$ = 1.99, 95% CI = 1.91, 2.09) or financial ($OR_{Very\ Low}$ = 1.22, 95% CI = 1.16, 1.28) capital have greater odds of having a marginal activity compared to agricultural labourers with a very high access to these capitals. On the contrary, odds to have a marginal activity increase when agricultural labourers have a lower access to household natural capital ($OR_{Very\ Low}$ = 0.36, 95% CI = 0.35, 0.38) or to household social capital ($OR_{Very\ Low}$ = 0.85, 95% CI = 0.81, 0.89).

Amongst community capitals, the model shows that agricultural labourers who have a very low access to community natural ($OR_{Very\ Low}$ = 0.83, 95% CI = 0.79, 0.86), physical ($OR_{Very\ Low}$ = 0.90, 95% CI = 0.87, 0.94) or social ($OR_{Very\ Low}$ = 0.73, 95% CI = 0.70, 0.77) capital are less likely to be employed for less than six months. However, a very low access to community human ($OR_{Very\ Low}$ = 1.16, 95% CI = 1.12, 1.20) or financial ($OR_{Very\ Low}$ = 1.20, 95% CI = 1.16, 1.26) capitals increases the odds of being marginal agricultural labourer.

Table 5.3: Results of the multilevel logistic models for agricultural labour. The dependent variable represents the odds of being agricultural labourer for workers engaged in agriculture. Model 1 is the null model in which only the confounders are considered. Model 2 tests the effect of household capitals. Model 3 takes the two levels of livelihood capitals into account.

Background characteristics and capitals	Model 1 OR [95% CI]	Model 2 OR [95% CI]	Model 3 OR [95% CI]
CONFOUNDERS			
District			
Puri	1.00	1.00	1.00
Khordha	1.37 [1.02, 1.85]*	1.36 [1.16, 1.61]***	1.27 [1.08, 1.51]**
Jagatsinghpur	0.86 [0.74, 0.99]*	1.48 [1.13, 1.95]**	1.43 [1.15, 1.79]**
Bhadrak	0.78 [0.66, 0.93]**	1.13 [0.87, 1.48]	1.05 [0.86, 1.30]
Kendrapara	0.71 [0.57, 0.88]**	0.95 [0.75, 1.20]	1.05 [1.10, 1.30]
Population Density	1.02 [0.99, 1.05]	0.53 [0.51, 0.55]***	0.58 [0.56, 0.60]***
Castes and Tribes	5.39 [5.10, 5.69]***	3.87 [3.67, 4.07]***	3.66 [3.44, 3.89]***
HOUSEHOLD CAPITALS			
Natural			
Very high		1.00	1.00
High		0.39 [0.38, 0.41]***	0.39 [0.37, 0.40]***
Moderate		0.30 [0.29, 0.31]***	0.29 [0.28, 0.30]***
Low		0.20 [0.19, 0.20]***	0.19 [0.18, 0.19]***
Very low		0.11 [0.11, 0.12]***	0.11 [0.11, 0.12]***
Physical			
Very high		1.00	1.00
High		1.15 [1.12, 1.18]***	1.15 [1.11, 1.19]***
Moderate		1.16 [1.13, 1.20]***	1.18 [1.15, 1.22]***
Low		1.17 [1.13, 1.20]***	1.20 [1.16, 1.24]***
Very low		1.24 [1.20, 1.28]***	1.28 [1.23, 1.33]***
Human			
Very high		1.00	1.00
High		1.49 [1.44, 1.55]***	1.52 [1.46, 1.58]***
Moderate		1.24 [1.20, 1.28]***	1.24 [1.20, 1.29]***
Low		1.18 [1.14, 1.22]***	1.17 [1.13, 1.21]***
Very low		1.18 [1.15, 1.22]***	1.17 [1.13, 1.20]***
Financial			
Very high		1.00	1.00
High		1.04 [1.01, 1.07]**	1.01 [0.98, 1.04]
Moderate		1.05 [1.02, 1.08]**	1.01 [0.98, 1.04]
Low		1.23 [1.19, 1.27]***	1.22 [1.18, 1.26]***
Very low		1.27 [1.22, 1.31]***	1.22 [1.18, 1.27]***
Social			
Very high		1.00	1.00
High		1.16 [1.13, 1.20]***	1.11 [1.08, 1.15]***
Moderate		1.16 [1.13, 1.20]***	1.11 [1.07, 1.15]***
Low		1.22 [1.18, 1.26]***	1.12 [1.08, 1.17]***
Very low		1.25 [1.20, 1.29]***	1.16 [1.12, 1.19]***
COMMUNITY CAPITALS			
Natural			
Very high			1.00
High			1.07 [1.04, 1.11]***
Moderate			1.08 [1.04, 1.12]***
Low			1.22 [1.18, 1.26]***
Very low			1.25 [1.20, 1.29]***
Physical			
Very high			1.00
High			0.98 [0.95, 1.01]
Moderate			1.01 [0.98, 1.04]
Low			1.09 [1.05, 1.13]***
Very low			1.12 [1.09, 1.16]***
Human			
Very high			1.00
High			1.00 [0.97, 1.03]
Moderate			1.01 [0.98, 1.04]
Low			1.04 [1.01, 1.07]*
Very low			1.15 [1.12, 1.19]***
Financial			
Very high			1.00
High			0.94 [0.92, 0.97]***
Moderate			0.91 [0.88, 0.94]***
Low			0.88 [0.86, 0.91]***
Very low			0.76 [0.73, 0.79]***
Social			
Very high			1.00
High			0.92 [0.90, 0.94]***
Moderate			0.91 [0.88, 0.94]***
Low			0.81 [0.79, 0.84]***
Very low			0.80 [0.77, 0.83]***
RANDOM EFFECTS			
Tehsil	1.16 [1.08, 1.24]***	1.13 [1.06, 1.19]***	1.14 [1.07, 1.21]***
Gram	2.97 [2.73, 3.24]***	2.21 [2.08, 2.36]***	2.21 [2.07, 2.35]***
Intersect	0.56 [0.52, 0.62]***	1.18 [1.09, 1.28]***	1.29 [1.16, 1.43]***

**Indicates a significance level of 0.01 *Indicates a significance level of 0.05

Table 5.4: Results of the multilevel logistic models for marginal agricultural labour. The dependent variable represents the odds of being a marginal agricultural labourer (less than six months) compared to being a main agricultural labourer (more than 6 months). Model 1 is the null model in which only the confounders are considered. Model 2 tests the effect of household capitals. Model 3 takes the two levels of livelihood capitals into account.

Background characteristics and capitals	Model 1 OR [95% CI]	Model 2 OR [95% CI]	Model 3 OR [95% CI]
CONFOUNDERS			
District			
Puri	1.00	1.00	1.00
Khordha	1.09 [0.88, 1.37]	0.99 [0.81, 1.21]	0.98 [0.81, 1.19]
Jagatsinghpur	1.09 [0.88, 1.35]	1.02 [0.85, 1.23]	1.08 [0.84, 1.40]
Bhadrak	1.08 [0.95, 1.23]	1.21 [0.95, 1.55]	1.17 [0.99, 1.38]
Kendrapara	1.06 [0.89, 1.26]	1.05 [0.90, 1.24]	1.09 [1.10, 1.39]
Population Density	1.25 [1.21, 1.30]***	0.97 [0.94, 1.01]	0.98 [0.95, 1.02]
Castes and Tribes	3.26 [3.04, 3.50]***	3.10 [2.92, 3.30]***	2.87 [2.68, 3.08]***
HOUSEHOLD CAPITALS			
Natural			
Very high		1.00	1.00
High		0.61 [0.59, 0.63]***	0.63 [0.61, 0.65]***
Moderate		0.53 [0.51, 0.55]***	0.54 [0.53, 0.56]***
Low		0.42 [0.40, 0.43]***	0.42 [0.41, 0.44]***
Very low		0.35 [0.34, 0.37]***	0.36 [0.35, 0.38]***
Physical			
Very high		1.00	1.00
High		1.00 [0.96, 1.03]	1.00 [0.96, 1.05]
Moderate		1.00 [0.96, 1.04]	1.02 [0.98, 1.07]
Low		1.17 [1.12, 1.22]***	1.18 [1.13, 1.24]***
Very low		1.29 [1.23, 1.34]***	1.33 [1.26, 1.40]***
Human			
Very high		1.00	1.00
High		1.14 [1.10, 1.18]***	1.12 [1.07, 1.17]***
Moderate		1.27 [1.22, 1.32]***	1.21 [1.17, 1.26]***
Low		1.45 [1.39, 1.51]***	1.42 [1.36, 1.48]***
Very low		2.06 [1.97, 2.16]***	1.99 [1.91, 2.09]***
Financial			
Very high		1.00	1.00
High		0.98 [0.94, 1.02]	1.02 [0.97, 1.07]
Moderate		1.08 [1.04, 1.12]***	1.10 [1.05, 1.15]***
Low		1.08 [1.03, 1.13]***	1.11 [1.05, 1.16]***
Very low		1.18 [1.13, 1.24]***	1.22 [1.16, 1.28]***
Social			
Very high		1.00	1.00
High		1.03 [0.99, 1.07]	1.03 [0.99, 1.07]
Moderate		1.02 [0.98, 1.07]	1.00 [0.96, 1.05]
Low		0.99 [0.95, 1.03]	0.96 [0.92, 1.01]
Very low		0.85 [0.82, 0.89]***	0.85 [0.81, 0.89]***
COMMUNITY CAPITALS			
Natural			
Very high			1.00
High			1.00 [0.96, 1.04]
Moderate			0.98 [0.94, 1.03]
Low			0.85 [0.82, 0.89]***
Very low			0.83 [0.79, 0.86]***
Physical			
Very high			1.00
High			1.00 [0.95, 1.04]
Moderate			0.98 [0.94, 1.03]
Low			0.97 [0.93, 1.01]
Very low			0.90 [0.87, 0.94]***
Human			
Very high			1.00
High			1.10 [1.06, 1.14]***
Moderate			1.11 [1.08, 1.15]***
Low			1.14 [1.09, 1.18]***
Very low			1.16 [1.12, 1.20]***
Financial			
Very high			1.00
High			1.03 [0.99, 1.08]
Moderate			1.07 [1.03, 1.11]***
Low			1.17 [1.13, 1.23]***
Very low			1.20 [1.16, 1.26]***
Social			
Very high			1.00
High			0.95 [0.91, 0.99]*
Moderate			0.92 [0.90, 0.95]***
Low			0.82 [0.79, 0.85]***
Very low			0.73 [0.70, 0.77]***
RANDOM EFFECTS			
Tehsil	1.05 [1.00, 1.10]*	1.04 [1.01, 1.08]**	1.05 [1.01, 1.09]**
Gram	5.94 [5.12, 6.90]***	5.32 [4.62, 6.12]***	5.40 [4.69, 6.22]***
Intersect	0.17 [0.16, 0.19]***	0.21 [0.19, 0.25]***	0.22 [0.19, 0.26]***

**Indicates a significance level of 0.01 *Indicates a significance level of 0.05

5.5 Discussion

The present chapter provides an innovative empirical development to livelihood studies by combining census data with satellite remote sensing products to explore the collective influence of household and community capitals on agricultural livelihoods. More specifically, the initial objective of this investigation was to demonstrate how both household and community capitals play a significant role in the likelihood of being a landless agricultural labourer, an association that has not yet been investigated. This chapter shows that community resources and household capitals should be considered separately as they do not necessarily have the same effects on the likelihood of being a landless agricultural labourer.

Rural India's most vulnerable households are daily-wage agricultural labourers and those who only have a marginal activity are considered as the poorest of the poor (Jatav and Sen, 2013; Lanjouw and Shariff, 2004; Pattenden, 2010). Engaging in such livelihoods is a source of distress for households, which drives migration and reinforces rural poverty (FAO, 2016). The combination of the findings emerging from this chapter shows that being a landless agricultural labourer is influenced by access to household capitals, which is consistent with previous research in the field of livelihood studies. However, the current chapter brings a new perspective on these associations by demonstrating that community capitals also have an influence on households' livelihood opportunities. A summary of the influence of both household and community capitals on agricultural labour is presented in Table 5.5.

Table 5.5: Likelihood to engage in agricultural labour. The results show the likelihood to engage in agricultural labour for agricultural households (left) and the likelihood to only have a marginal activity for agricultural labourers (right). The results presented here are derived from the models including both community and household livelihood capitals. Arrows represent the direction of significant associations.

Livelihood capitals		**Agricultural livelihood activities**	
Type	Level	Agricultural labourer (compared to cultivator)	Marginal agricultural labourer (compared to main)
Natural	*Household*	↑	↑
	Community	↓	↑
Physical	*Household*	↓	↓
	Community	↓	↑
Human	*Household*	↓	↓
	Community	↓	↓
Financial	*Household*	↓	↓
	Community	↑	↓
Social	*Household*	↓	↓
	Community	↑	↑

5.5.1 Livelihood capitals and agricultural labour

Natural capital. The chapter showed significant associations between household natural capital and levels of agricultural labour. Communities with larger farms (including cropland, tree plantation and pasture) are more likely to have a larger proportion of households engaging in agricultural labour, and especially in marginal agricultural labour. This result confirms the findings of van den Berg (2010) and Manjunatha et al. (2013) who demonstrated that households are more likely to engage in precarious forms of employment when they are located in communities where natural resources are only owned by few large-scale farmers. Smallholders sell their land to larger farm holders as a result from their incapacity to cope with recurrent crop failures, driving them into agricultural labour (Levien, 2013). On the other hand, the findings show that households located in communities with a greater access to community natural capital are less likely to be agricultural labourers. This finding provides further support to the hypothesis that greater access to common-pool natural resources enables more households to engage in cultivation (de Sherbinin et al., 2008). However, the results also show that agricultural labourers are more likely to have a marginal activity when they are located in a village with a great community natural capital. This finding supports the hypothesis that communities with access to irrigation facilities require less labour throughout the year compared to rainfed agricultural systems.

Physical capital. The results show that access to means of transportation and electricity is negatively associated with agricultural labour. This finding corroborates the qualitative findings from Chapter 3, which showed that electricity allows farmers to operate motor pumps for irrigation, enabling them to get extra income through the cultivation of vegetable gardens and thus to remain as cultivators. Private means of transportation, on the other hand, enable households to reach more marketing outlets to sell their agricultural products or buy agricultural inputs (confirming the results from Birthal et al., 2013; Levien, 2013; Mearns and Sinha, 1999). Regarding community physical capital, the results show a negative effect of the proximity to markets and industrial areas on the odds of engaging in agricultural labour. The results of this chapter also show that agricultural labourers who are located in communities with a greater community physical capital are more likely to be engaged in marginal employment. These two observations support the hypothesis that proximity to markets is associated with smaller farm holdings who cannot provide a stable source of agricultural employment, thus reducing the need for agricultural labour and reducing the likelihood of being hired throughout the year (Birthal et al., 2013; Levien, 2013).

Human capital. The findings show that access to human household capital reduces the likelihood of engaging in agricultural labour for agricultural households, and reduces the likelihood of being employed marginally for agricultural labourers. Similarly, proximity to education and health facilities also reduce the likelihood of engaging in agricultural labour. A strong human capital enables households to be more resilient to climatic shocks by looking for

temporary income-generating activities after facing an external shock and thus preventing them from selling their land and engage in agricultural labour (Jansen et al., 2006). This important result was confirmed by participants during the focus groups who argued that households with more than two working age members are able to send one to look for daily-wage work while the other one looked after the farm when they needed cash. It also increases the availability of workforce during peaks of labour, such as crop establishment and harvest, during which all members work on the farm, reducing the need for extra labour costs. This corroborates previous findings which showed that access to household human capital increases the chances of adopting mechanised commercial farming and to generate sustainable incomes (Eneyew and Bekele, 2012; Paudel Khatiwada et al., 2017; Reardon, 1997).

Financial capital. The results show that access to financial household capital reduces the likelihood for households to engage in agricultural labour. Access to financial services and the ownership of protective equipment (assets that can be sold if the household faces a shock) enable households to cope with crop failure and thus prevent them to sell their land after facing a shock. This corroborates previous findings who showed that access to household financial capital enables households to reduce the barriers to retaining a remunerative on-farm livelihood strategy such as cultivation (Babulo et al., 2008; Fang et al., 2014; Jiao et al., 2017). Therefore, households that lack access to financial capital are more likely to sell their productive assets and thus to engage in agricultural labour. Land dispossession due to indebtedness was confirmed during the focus groups: households sell their land to cope with an external shock and become landless farmers. Interestingly, although participants flagged proximity to financial services as an important capital for their livelihood opportunities, the results from this chapter show that agricultural households who benefit from a greater access to community financial capital are more likely to be landless agricultural labourers. This rather counter-intuitive result is explained by the fact that proximity to financial institutions goes hand in hand with external investments that increase the pressure on farm holdings, thus encouraging smallholders' land dispossession by larger farm holders (Birthal et al., 2013; Levien, 2013; Mearns and Sinha, 1999). Therefore, community financial capital indirectly increases the likelihood of being an agricultural labourer rather than a cultivator. The issue that emerges from these findings is that access to financial services (household financial capital) is a greater barrier to credit than physical access to banks (community financial capital), as households may rely on informal credit sources when they lack physical access to financial infrastructures, which trap them further into poverty.

Social capital. A low household social capital (weak kinship ties) is found to increase the likelihood to engage in daily-wage agricultural labour compared to cultivation for agricultural households, a result which mirrors the observations of Mearns and Sinha (1999); Gang et al. (2008) who showed that socially excluded groups suffered from land market exclusion and a lack of employment opportunities. On the other hand, households with a strong access to household social capital are less likely to be marginal agricultural labourers, thanks to their social networks that provide them with greater employment opportunities (Krishna and Uphoff,

1999; Collier, 2002). However, agricultural labourers who have access to a high community social capital are more likely to engage in marginal activities. The availability of recreational facilities (e.g.cinemas, stadiums, playgrounds) and of unions gives a greater possibility of kinship ties (Krishna and Uphoff, 1999), which goes hand in hand with participation in such groups (Erenstein et al., 2010; Soltani et al., 2012; Fang et al., 2014) or enable households to move away from agricultural activities by providing them with off-farm livelihood alternatives. As mentioned during one focus group, this finding can be attributed to the time invested in such unions, especially Self-Help Groups, in order to develop income-generating activities for the future (Leana and van Buren, 1999; Pattenden, 2010; Datta, 2015). In such a case, households' strategy is to keep a marginal labour activity to enable their members to get involved in the development of self-enterprise income-generating activities.

5.5.2 Population density and agricultural labour

Rural population density has a major influence on the social and demographic aspects of rural communities, yet there are only few analyses of their associations with agricultural labour employment (Smailes et al., 2002), most studies having looked at the associations between population density and agricultural intensification (e.g. Headey et al., 2010; Josephson et al., 2014; Muyanga and Jayne, 2014; Pender et al., 2004; Smailes et al., 2002). The results from this chapter show that agricultural households are less likely to be agricultural labourers in densely populated communities. This can be explained by the increased pressure on farm holdings in these areas, which encourages smallholders' land dispossession by larger farm holders (Birthal et al., 2013; Levien, 2013; Mearns and Sinha, 1999). These newly landless agricultural households move out from agriculture and benefit from the economic opportunities that exist in highly dense areas to find off-farm livelihood alternatives (Muyanga and Jayne, 2014). Another finding concerns agricultural households who live in the districts of Khordha and Jagatsinghpur: it appears that households from these districts have a greater likelihood to engage in agricultural labour. These results echo the findings from DECCMA (2017) who demonstrated that there were high rates of emigration from these districts, partly due to the low incomes cultivators get from their farm and to the high proportion of agricultural labourers.

5.5.3 Castes and agricultural labour

Although the caste system is no longer connected to the type of activities conducted by its members, high status employment is dominated by upper caste, while physical labour and low status jobs are mostly performed by lower caste or dalit (Chapter 2). Social and cultural norms in India limit people from the lowest caste to exercise their right to own and manage land and productive assets. As a consequence, landowners only rent land to farmers that are perceived as less risky, such as large farmers or farmers from the same socio-economic class and caste. Such a structure of land relations work as a barrier against scheduled castes and scheduled tribes' economic agency and legal entitlements by preventing them to get

access to land (Mohanakumar, 2014; Kelkar and Kumar Jha, 2016). By controlling for the proportion of scheduled castes and tribes, the findings from this chapter show that belonging to disadvantaged castes is the underlying driver that explains the proportion of agricultural labour in a community.

5.6 Conclusion

The present chapter sought to determine the influence of community capitals and household capitals on precarious agricultural livelihoods. The findings from this chapter confirm that belonging to disadvantaged castes is the main parameter to explain people's likelihood to engage in precarious livelihoods. However, they also bring a new perspective on these associations by demonstrating that apart from power relationships of class and caste, community resources and household capitals also have an effect on driving precarious agricultural livelihoods. This chapter shows that community resources and household capitals should be considered separately as they do not necessarily have the same effects on the likelihood of being a landless agricultural labourer. The approach used in this chapter using multi-level modelling is an appropriate framework to support this differentiation.

The results show that access to physical, human, financial and social household capitals reduces the likelihood to engage in precarious forms of labour (daily-wage agricultural labour) for agricultural households. The findings suggest that households are more likely to be landless agricultural labourers near well-connected rural centres, due to smallholders' land dispossession by larger farm holders. Another important result is that agricultural labourers are more likely to have a marginal employment in remote areas, which makes them amongst the poorest socio-economical group in rural India. These findings suggest that investment in rural infrastructure might increase livelihood vulnerability if not accompanied by an improvement in the provisioning of complementary rural services, such as access to rural finance, and by the implementation of agricultural tenancy laws to protect smallholders' productive assets.

CHAPTER 6 Climate extremes and the geographies of livelihood precariousness

Spatial factors, such as environmental conditions, distance to natural resources and access to services shape differential vulnerabilities and influence the impacts of climate change on rural households. This chapter investigates how place influences the drivers of livelihood precariousness. A typology of rural communities in the Mahanadi Delta is defined by clustering characteristic variables of community capitals, focused on natural resources, social services and productive infrastructures. Based on this typology, associations between agricultural shocks, household capitals and precarious livelihood strategies are characterised for each community type to show how the type of community influences the impact of climatic shocks on livelihoods and changes the direction of the relationships between capitals and livelihood strategies. This chapter demonstrates that the bundle of locally available community capitals modifies households' coping strategies and livelihood opportunities, thus influencing the drivers of rural poverty. The results suggest that poverty alleviation programmes should include community typologies in their approach to provide place-specific interventions that would strengthen context-specific household capitals, thus reducing livelihood precariousness.

Data and methods from this chapter were presented at the ESPA Delta Final UK Event in London (UK), November 2016 and at the EGU General Meeting in Vienna (Austria), April 2017. Results from this chapter were presented at the FAO Expert Workshop on Socio-ecological Systems in Rome (Italy), January 2018 and at the AAG Conference in New Orleans (USA), April 2018.

6.1 Introduction

Despite the recommendations from previous poverty studies (Benson et al., 2005; Farrow et al., 2005; Okwi et al., 2007; Vincent, 2007; Kim et al., 2016) and from livelihood studies (Smith et al., 2001; Kristjanson et al., 2009; Angelsen et al., 2011) that have shown the importance of place-based approaches to rural poverty, there have been very few studies that have characterised the place-based sensitivity of livelihood strategies to livelihood capitals and external shocks. To the author's best knowledge, the only study that looked at the influence of place on the associations between livelihood capitals and livelihood strategies relied on an arbitrary categorisation of community types based on a total of six settlements (Fang et al., 2014). Although this paper demonstrated that different settlement types affect how access to capitals influences households' livelihood strategies, the interpretation of the results was micro-localised and difficult to reproduce across a larger spatial extent. Besides, understanding the links between multiple stressors and livelihoods is central to achieving sustainable development pathways (Dasgupta et al., 2014). However, insufficient work assesses the spatial distribution of livelihoods as a consequence of climatic stressors (Olsson et al., 2014). This chapter aims to address this research gap by conducting a place-based analysis of the influence of livelihood capitals and agricultural shocks on precarious livelihood strategies.

Typologies are useful tools of analysis for policy-makers, planners and other practitioners to improve place-specific understandings of rural heterogeneity and rural change (Copus et al., 2008). The multidimensionality of rural heterogeneity can be categorised into community typologies that reflect similar combinations of natural resources (i.e., water, cropland, forest), social services (including education, health, governance), and productive infrastructures (Pahl, 1966; Alessa et al., 2009). These different combinations of assets reflect different underlying types of communities (Hedlund, 2016), which influence the drivers of livelihood strategies and rural poverty (Fang et al., 2014), and therefore lead to different responses to multiple stressors. The objective of this chapter is to demonstrate how the type of rural community in which households are situated modifies the relationships between agricultural shocks and access to livelihood capitals on one side, and livelihood strategies on the other side (Objective 3 and 4). A typology of rural communities in the Mahanadi Delta is defined by clustering characteristic indicators of community capitals as identified in Chapters 3 and 4, focused on natural resources, social services and productive infrastructures. Based on this typology and on the findings from the previous chapters (Chapters 3,4 and 5), the associations between agricultural shocks, household capitals and precarious livelihood strategies are then characterised for each community type to show how the type of community influences the impact of climatic shocks on livelihoods and changes the direction of the relationships between capitals and livelihood strategies. This chapter demonstrates that the bundle of locally available community capitals influences households' coping strategies and livelihood opportunities. Agricultural shocks drive livelihood precariousness, while access to capitals, which is conditioned by power relationships of class and caste, tends to reduce it. The results suggest that poverty alleviation programmes should include community typologies in their approach to provide place-specific interventions that

would strengthen context-specific household capitals, thus reducing livelihood precariousness.

6.2 Conceptual framework

Figure 6.1 presents the dynamic multilevel livelihood framework used in this chapter, which is based on the household livelihood strategy framework (Winters et al., 2001; Nielsen et al., 2013) and the findings from Chapters 3 and 5. As seen previously, a livelihood system gathers the capabilities, assets and activities of one household to achieve its means of living (Chapter 2). Assets are resources that people have access to, which can be private goods (household capitals) or public goods (community capitals). Household assets are grouped into a set of five livelihood capitals: natural (natural resource stocks), physical (productive assets), financial (liquidities and protective assets), human (capabilities and capacities of the households) and social (networks and kinships). Similarly, three categories of community capitals can be grouped (Chapter 4 and Flora et al., 2015): natural resources, social services (access to social amenities) and productive infrastructures (road networks, markets and industries). Based on their access to community and household assets, households put in place a range of livelihood activities to achieve their basic needs (Chapter 5). Apart from the influence of power relationships of class and castes, livelihood opportunities depend on the household and community capitals that households have access to (Fenichel et al., 2016). However, households sometimes face shocks that prevent them from achieving the expected outcomes, forcing them into place-based coping strategies (Scoones, 1998).

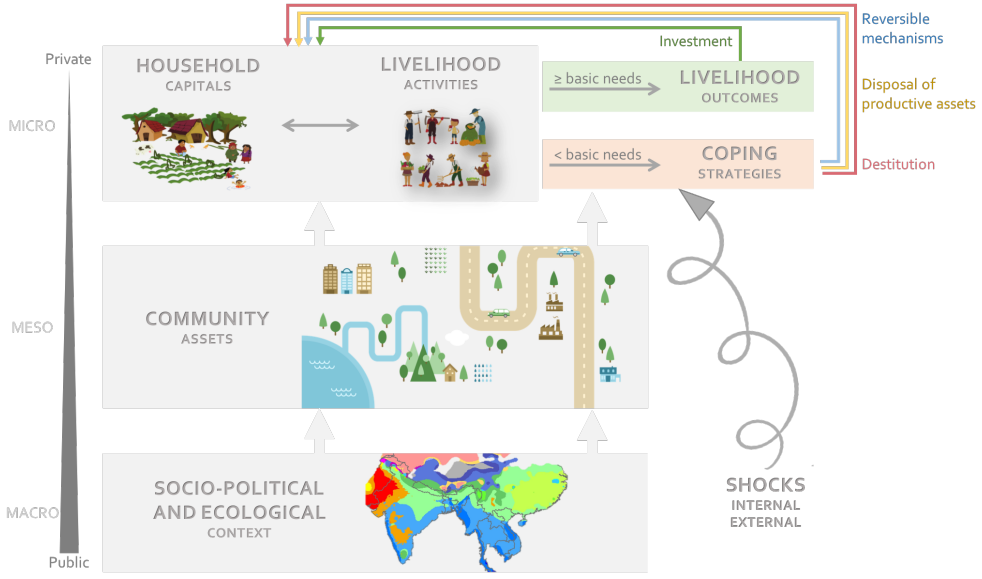


Figure 6.1: Dynamic multilevel livelihood framework. The combination of capitals and activities lead to livelihood outcomes if the household does not face any shocks, which are reinvested in the system. In the case of a shock (internal or external), households can implement three types of coping strategies depending on their assets and public assets from the community they live in: reversible mechanisms (activity shift, sell of protective assets), disposal of productive assets (sell land) and destitution (unemployment, distress migration).

Coping strategies are defined as temporary adjustments made by households in their livelihood

systems in response to shocks, which can be external (natural hazards, movements in markets, changes in policy environment) or internal (health problems, changes in household composition, social rituals) (Carney, 1998; Scoones, 2015). Three different types of coping mechanisms can be highlighted based on their reversibility (Chen and Dunn, 1996; Mutangadura et al., 1999; Kabir et al., 2000): (i) reversible mechanisms (temporary activity shift, disposal of protective assets); (ii) erosive mechanisms (disposal of productive assets such as land); and (iii) destitution (unemployment, distress migration). Reversible mechanisms can be observed when some members take wage labour or migrate to find paid work (temporary activity shift) or when using self-insurance mechanisms, such as selling protective assets (Chen and Dunn, 1996). Protective assets include any asset held as a store of value and that can be sold if the household faces an external shock, including cash, jewellery or livestock (Kent and Dorward, 2012; Chena et al., 2013). Erosive mechanisms are usually implemented in response to heavy shocks or persisting stresses and undermine households' productive capacity. In the case of disposal of agricultural land, this leads to a long-term livelihood change, as households shift from cultivation to other activities, for example, agricultural labour (Himanshu et al., 2013). The last category of coping mechanisms comes as a last resort for the household and indicates its destitution, with household members becoming unemployed or choosing permanent out-migration.

This framework shows the different components used in this chapter to understand how access to community capitals can influence the relationship between household capitals and livelihood activities, and the impacts of climatic shocks on livelihood systems. The next section presents how bundles of community assets were categorised by using clustering methods, how climate shocks were proxied by using time-series analysis, and how the associations between shocks, household capitals and livelihood strategies were modelled by using multilevel regression modelling.

6.3 Materials and methods

This research focused on an area covering the five districts of the Mahanadi Delta in Odisha, eastern India (Figure 3.1). Given that communities are statutory units in India with a definite boundary and separate land records, the administrative boundaries provided by the Registrar General and Census Commissioner (2011) were used for the analysis. Urban areas were removed from the data using the census "`ADMIN_RURAL_URBAN`" variable. In total, 9,829 rural communities were considered, nested within 67 Tehsils, themselves nested within five districts. This section presents the data and methods used for developing community typologies, quantifying livelihood capitals and proxying climate shocks. The last subsection presents how the former components were used together in a statistical modelling framework to characterise the place-based associations between agricultural shocks, household capitals and precarious livelihood strategies.

6.3.1 Developing Community Typologies

Communities have access to common-pool resources (i.e. road, market, forest, lake) that can provide services for rural dwellers' livelihoods. For example, a road can provide farmers with alternative outlets for their agricultural production, while a forest can give the opportunity for households to collect and sell non-timber forest products. Such common-pool resources appear together repeatedly in the landscape, creating bundles of community capitals (Bański and Mazur, 2016; Hedlund, 2016; Martín-López et al., 2017). Cluster analysis was used on 18 variables derived from open source data to generate community typologies (Raudsepp-Hearne et al., 2010; Mouchet et al., 2014; Hedlund, 2016)[1]. Indicators were selected based on the findings from Chapter 3 and focused on natural resources, social services and productive infrastructures. Participants argued that remoteness plays an important role in their access to community capitals, and thus in their choice of livelihood strategy. As a consequence, travel time distance to key amenities was used rather than amenity availability to reflect community remoteness in the cluster analysis. Euclidean distances are inappropriate for this purpose as the Mahanadi Delta has several water bodies, which act as boundaries to travel (Black et al., 2004). Accessibility to key amenities was thus estimated by creating a least accumulative cost surface to estimate time to travel from each community to the nearest amenity of interest.

Estimating accessibility. Road data was downloaded from OpenStreetMap (OpenStreetMap Contributors, 2017), using the R (R Development Core Team, 2015) package `osmdata`[2] (Padgham et al., 2017), which contained the following tags: trunk; primary; secondary; tertiary; and footpath. Roads were then converted to a raster at 30 metres spatial resolution and merged with 30 metres spatial resolution land cover data from 2011 GlobeLand30 (Bartholomé and Belward, 2005; Chen et al., 2014). Average speeds were assigned to each land cover class, following the methods from previous studies (Noor et al., 2006; Nelson, 2008; Watmough et al., 2016) and are presented in Table 6.1.

Variables for community typologies. In total, 18 variables were chosen to be included in the cluster analysis (Table 6.2). These were selected to represent the diversity of drivers that were highlighted by participants during the rapid rural appraisals (Chapter 3). They can be grouped into three categories, natural resources, social services and productive infrastructure. Locations of the main amenities were extracted from the Village Amenities tables of the 2011 Indian National Population and Household Census (Registrar General and Census Commissioner, 2011) and from OpenStreetMap data (OpenStreetMap Contributors, 2017). MODIS data at 250 metres spatial resolution from 2010 was used to obtain a land cover dataset detailing the different types of cropping systems found in the delta (Gumma et al., 2014). Travel costs to the nearest amenity of interest were computed from the least accumulative cost surface dataset mentioned previously. In situations where multiple indicators for the same service were found

[1] See Appendix D for the R scripts
[2] Available from GitHub at `https://github.com/ropensci/osmdata`

Table 6.1: Estimated travel speeds for different land cover types. Used to generate travel cost to nearest amenities and based on values from Noor et al. (2006), Nelson (2008) and Watmough et al. (2016).

Class	Estimated speed (min.km^{-1})
ROAD TYPE	
Trunk	0.6
Primary	0.8
Secondary	1.2
Tertiary	2.0
Footpath	20.0
LAND COVER	
Water	20.0
Evergreen needleleaf trees	36.0
Evergreen broadleaf trees	60.0
Deciduous needleleaf trees	48.0
Deciduous broadleaf trees	36.0
Shrub	36.0
Grass	24.0
Cereal crops	36.0
Broadleaf crops	36.0
Urban and built-up	2.0
Barren or sparse vegetation	24.0

(type of education or health facility), the indicator that exhibited the greatest variation among communities was favoured. Travel times to six types of amenities were chosen to reflect access to social services: public services and polling stations, secondary schools, banks and credit cooperatives, hospitals, worship temples and recreational areas, such as sports centres and playgrounds. Three amenities were used to reflect access to productive infrastructures: travel time to communication services, agricultural outlets and industrial areas. Availability of public transport was also chosen to represent productive infrastructures, as they can be used by smallholders to access agricultural markets (Roy and Thorat, 2008; Markelova et al., 2009). Eight variables were chosen to reflect the natural resources from which most households derived their incomes, seven of which were derived from satellite sensor data and one from OSM. These variables included: the area of forest (which is a source of timber and non-timber products), the area of cropland available per household, the type of agricultural system (based on the proportion of each cropping pattern within the community) and the travel time from each community to the nearest aquaculture ponds. These variables were chosen since the number of growing seasons and the availability of irrigation systems can be a determinant for livelihood outcomes (Fan et al., 2000).

Clustering method. A hierarchical model-based clustering method was used to avoid the heuristic bias of hierarchical and k-means clustering algorithms, which is due to the arbitrary approach in determining the number of clusters and defining them (Fraley, 1998). Model-based clustering considers the data as coming from a distribution that is a mixture of two or more clusters, and assigns to each data point a probability of belonging to each cluster (Fraley and Raftery, 2002). Each cluster is modelled by the Gaussian distribution and is characterised by its

Table 6.2: Variables used for community typologies. Indicators for social services are based on travel times to the closest service found by using a least accumulative cost surface dataset, computed from road networks and land cover data. Natural services are derived from agricultural-relevant landscape metrics from land cover data.

Variables	Description	Source
NATURAL RESOURCES		
Forest	Total area of forest	MODIS
Cropland	Total area of cropland	MODIS
Single rainfed	Proportion of cropland cultivated as single rice rainfed	MODIS
Single mixed	Proportion of cropland cultivated as single mixed crops rainfed	MODIS
Single irrigated	Proportion of cropland cultivated as single rice irrigated	MODIS
Double irrigated	Proportion of cropland cultivated as double rice irrigated	MODIS
Triple irrigated	Proportion of cropland cultivated as triple rice irrigated	MODIS
Aquaculture	Travel time to aquaculture farms	OSM
SOCIAL SERVICES		
Official	Travel time to public services and polling station	Census
Education	Travel time to secondary school	Census
Banks	Travel time to closest financial service amenity	Census
Health	Travel time to nearest hospital	Census
Worship	Travel time to closest worship area	OSM
Recreation	Travel time to closest recreation area	OSM
PRODUCTIVE INFRASTRUCTURES		
Transport	Availability of public transport	Census
Communication	Travel time to closest communication services (public phone, post)	Census
Market	Travel time to closest market or agricultural outlet	Census
Industry	Travel time to industrial area	OSM

mean vector, covariance matrix and the probability of each point belonging to this cluster. These parameters are estimated using the Expectation-Maximisation algorithm, which is initialised by hierarchical model-based clustering. The covariance matrix determines the geometric shape of each cluster, the latter being centred at the mean, around which there is an increased density of points. The model with the greatest integrated likelihood, or Bayesian Information Criterion (BIC), is considered as the best fitting model. The `R` (R Development Core Team, 2015) package `mclust`[3] (Fraley and Raftery, 2002; Fraley et al., 2012) was used to implement the model-based clustering algorithm, which estimated the best finite mixture model according to different covariance structures and different numbers of clusters.

6.3.2 Quantifying livelihood capitals

The quantification of livelihood capitals was based on register data at the community level from a subset of the 2011 Indian National Population and Household Census (Registrar General and Census Commissioner, 2011). A weighted index was created for each type of capital using variables from the Indian Census 2011. As all variables were continuous, the weights were estimated using principal components analysis (PCA), a data reduction technique that transforms a set of correlated variables into a set of orthogonal (un-correlated) principal components (PC) which are linear combinations of the original variables (Filmer and Pritchett, 2001). The PCA was run for each livelihood capital separately (five in total) on a selected set of variables that were identified through rapid rural appraisals conducted in ten communities in the Mahanadi

[3] Available from the Comprehensive R Archive Network (CRAN) at `http://CRAN.R-project.org/`

Delta in India between February and May 2016. The variables used in the PCA are similar to the variables used in Chapter 5, which proxied the participants' views regarding the capitals that they perceived as determinant for their livelihood opportunities (Table 4.1, page 89).

6.3.3 Proxying climate shocks

Extreme events, such as heat waves, droughts, floods and cyclones are becoming more frequent and both their frequency and intensity are likely to increase in the future (Karl and Katz, 2012; IPCC, 2013; Pfahl et al., 2017). Given the key role of climate for agriculture, extreme climatic events can lead to agricultural losses, which can lead to shifts from transient to chronic poverty (Porter and Semenov, 2005; Olsson et al., 2014; Béné et al., 2016). Decreases in agricultural production can be identified by remotely sensed satellite sensor data in the form of abrupt changes in vegetation greening (Liu et al., 2013). This section presents the materials and methods used to detect decreases in agricultural production, which are used as proxies of severe climatic shocks.

Choosing a vegetation index to capture crop production. Various vegetation indices exist, either based on a combination of surface reflectance spectral bands such as the normalised difference vegetation index (NDVI) and the enhanced vegetation index (EVI); or based on biophysical variables such as the leaf area index (LAI). The most widely used index is the NDVI, which has been used for land cover classification based on phenology (Yui et al., 2004; Xie et al., 2008; Zhong et al., 2011; Clerici et al., 2012; Xue et al., 2014; Yan et al., 2015), forecasting crop yield (Basso et al., 2013; Imran et al., 2014), assessing the impact of climate extremes on vegetation (Ma et al., 2015), quantifying CO_2 fluxes (Wylie et al., 2003), detecting standing water and floods (Guerschman et al., 2011; Domenikiotis, 2003), assessing food prices and food security (Brown and Funk, 2008; de Beurs and Brown, 2009; Brown et al., 2012) and even understanding poverty-environment relationships (Watmough et al., 2013; Imran et al., 2014). However, it has been shown that it saturates at high biomass levels and is sensitive to soil and background effects (Huete et al., 2002; Chen et al., 2006). Thus, the Wide Dynamic Range Vegetation Index (WDRVI) developed by Gitelson (2004) was used as it preserves a linear relationship with lead area index and vegetation fraction. Moreover, it captures well crop growth dynamics (Guindin-Garcia et al., 2012) and was found to be more accurate than both NDVI and EVI at estimating crop yield over the Mahanadi Delta (Duncan et al., 2015). The index is calculated following the equation:

$$WDRVI = \frac{\alpha * \rho_{NIR} - \rho_{red}}{\alpha * \rho_{NIR} + \rho_{red}}, \tag{6.1}$$

where ρ_{NIR} is the near-infrared reflectance, ρ_{red} the red reflectance and α a weighting parameter selected by the user. The addition of the weighting parameter α enables the WDRVI to enhance its dynamic range, which is limited by the NDVI under conditions of moderate to high biomass, such as in the Mahanadi Delta (Gitelson, 2004; Viña et al., 2004; Duncan et al., 2015). A weighting of $\alpha = 0.20$ was used, as it has been found to be the optimum value with proximal sensors, such as MODIS (Henebry et al., 2004; Viña et al., 2004). Band 1 (ρ_{red}, 620-670 nm) and

band 2 (ρ_{NIR}, 841-876 nm) from MODIS surface reflectance products were used to compute the WDRVI at a spatial resolution of 250 metres and a temporal resolution of every eight days for the time period 2000 to 2011. The eight-days composite Level 3 products (MOD09A1) at 250 metres resolution were downloaded for the time period 2000 to 2014[4], mosaiced and reprojected using the MODIS Reprojection Tool[5].

Detecting breaks in crop production. The Breaks For Additive Season and Trend (BFAST) technique was used to detect changes in time-series of WDRVI to identify crop failures[6]. The BFAST method estimates the dates, the magnitude and direction of change without setting a threshold or defining a reference period, and thus can be used to characterise changes occurring in seasonal and trend components. The general decomposition model fits a piecewise linear trend T_t and a seasonal model S_t, and is of the form: $Y_t = T - t + S_t + e_t$, with $t = 1, \ldots, n$. The ordinary least squares (OLS) residuals-based MOving SUM (MOSUM) test is used to detect whether one or more breakpoints are occurring. If breaks are occurring, the number and position of breaks are determined by minimising the residual sum of squares and by minimising an information criterion, such as the Bayesian Information Criterion (BIC) (Zeileis et al., 2002). Both trend and seasonal components are fixed between breakpoints. However, they can vary across them. The intercept and slope of consecutive linear models are used to characterise the magnitude and direction of abrupt changes in the trend. This method was used to determine the number, type, and timing of trend and seasonal changes within historical time-series (Verbesselt et al., 2010). It was also used for the detection of disturbances in time-series by automatically identifying and modelling its stable history parts (Verbesselt et al., 2012).

Figure 6.2 presents the outputs from the break detection in the WDRVI time-series, where only negative breaks were considered. Thanks to the linear correlation that exists between WDRVI and crop yield over the Mahanadi Delta (Duncan et al., 2015), breaks in WDRVI time-series represent abrupt changes in crop production, and negative breaks are thus considered to represent crop failures. Moreover, Watts and Laffan (2014) showed that breaks in vegetation indices detected by BFAST corresponded with the timing of known floods in the study region for between 68% and 79% of breaks detected across the sample pixels. Taken together, these studies indicate that the BFAST method is able to detect abrupt changes in vegetation greening caused by climatic hazards. Negative breaks in the WDRVI time-series were thus considered as proxies of climatic shocks that had a negative impact on crop production.

6.3.4 Statistical modelling

Detailed examinations of poverty structures in rural India show that households engaged in agricultural labour or unemployed are the poorest of the rural poor (Ravi and Engler, 2015). The

[4] The products were retrieved using a R script running on the ftp server of MODIS `http://e4ftl01.cr.usgs.gov`

[5] Courtesy of the NASA EOSDIS Land Processes Distributed Active Archive Centre (LP DAAC) `https://lpdaac.usgs.gov/tools/modis_reprojection_tool`

[6] See Appendix D for the R scripts

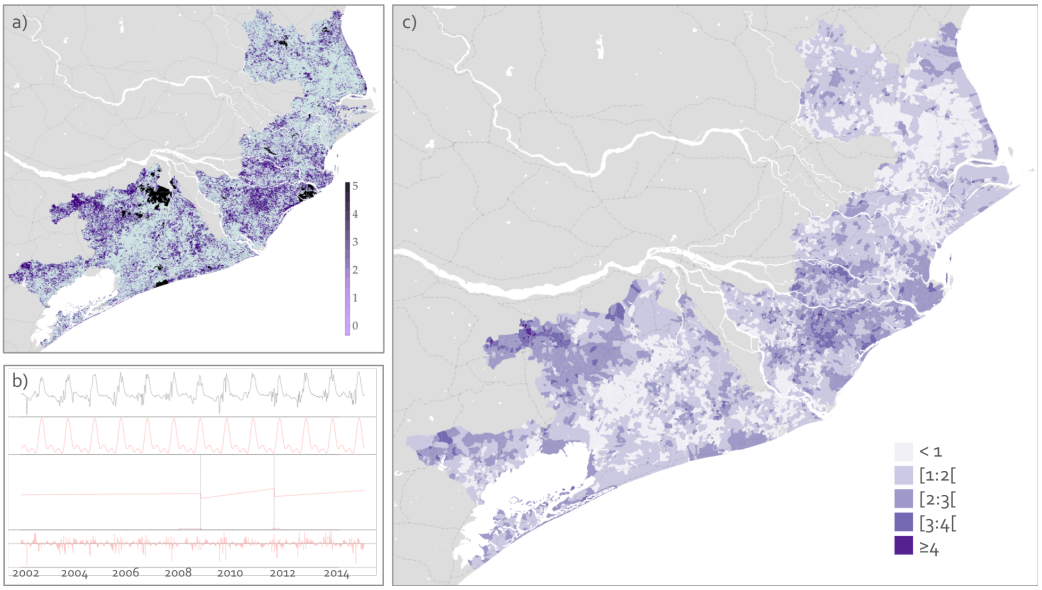


Figure 6.2: Breaks in WDRVI time series detected using BFAST. Negative WDRVI anomalies represent the number of decreases in agricultural production shown at 250 m resolution for croplands (a) and averaged at the community level for modelling purposes (c). For each pixel, the time series is decomposed into its seasonal and trend components to identify breakpoints using the Breaks For Additive Season and Trend (BFAST) technique. (b) shows an example of the decomposition of the WDRVI time series for one random pixel, highlighting two breaks.

response variable reflects this finding and represents the proportion of working-age people (15-59) who are engaged in agricultural labour or unemployed. Contextual factors, such as socio-political and ecological contexts, also strongly impact livelihood opportunities, outcomes and the ability for households to implement coping strategies (Jiao et al., 2017; Cinner et al., 2018). Multilevel regression techniques are used to control for such factors, by allowing the model to vary at the Tehsil level (administrative division level 3, earmarked for administration and development in India). To characterise how community typologies affect the influence of livelihood capitals and crop failures on precarious livelihood activities, separate models were fitted for each one of the community types identified through model-based clustering. To identify the true effects of household capitals and crop failures, the models accounted for several confounders (districts to which the communities belong, population density of the communities, ratio of scheduled castes and tribes) and random effects. For each community type, a two-level random intercept model was fitted using the `R` (R Development Core Team, 2015) package `R2MLwiN` (Charlton et al., 2017; Rasbash et al., 2005):

$$logit_{\text{Cluster}}(\pi_{ij}) = log(\frac{\pi_{ij}}{1-\pi_{ij}}) = \beta_{oj} + \beta_1 \text{District}_{ij} + \beta_2 \text{PopDensity}_{ij} + \beta_3 \text{SCST}_{ij} + \beta_4 \text{Breaks}_{ij}^{\text{WDRVI}} + \beta_5 \text{Natural}_{ij} + \beta_6 \text{Physical}_{ij} + \beta_7 \text{Human}_{ij} + \beta_8 \text{Financial}_{ij} + \beta_9 \text{Social}_{ij}, \tag{6.2}$$

where π_{ij} refers to the probability of being engaged in precarious livelihoods (unemployment and agricultural labour) for the community i in the *Tehsil* j. The random effect β_{0j} is defined as the sum of the intercept β_0 and a random effect varying at the Tehsil level U_{oj}. Each level 1

unit (community) had an associated denominator n_i, which was the total number of people of working age: every person aged 15-59, as defined by the Registrar General and Census Commissioner (2011). Two sets of explanatory variables were considered: livelihood capitals and the number of breaks in the WDRVI time-series, as a proxy of the number of crop failures. As the response variable is binomial, a linearisation method in the model was used to transform the discrete response model (binomial) to a continuous response model (Goldstein, 2003), with a Maximum Likelihood modelling approximation method to estimate the unknown parameters of interest in the model.

6.4 Results

6.4.1 Typology of rural communities

The clustering of eighteen variables in three domains (natural resources, social services and productive infrastructures) resulted in five distinct clusters being identified. These formed the basis for five community typologies that could be used to investigate how place influences the relationships between shocks, household capitals and livelihood precariousness. The five clusters identified were spatially clustered in the landscape (Figure 6.3), with the number of communities in each cluster ranging from 409 to 2,563. Each cluster was named based on the type of services available to the community and on the dominant land cover class.

Exurban communities. This cluster reveals a clear geographic profile, with a total of 2,245 communities (total population of 1,928,232) located in the near vicinity of main roads. It reveals characteristics that are ascribed to communities well connected to urban and peri-urban areas, corresponding to the definition of exurbs (Bell, 1992). This cluster is characterised by a high availability of public transport and its proximity to markets (travel time of 19 minutes on average) and industries (travel time of 1h29 minutes on average). Communities in this cluster also have a high access to social services such as education (travel time of 10 minutes on average) and health facilities (average travel time of 45 minutes), and are located near local official institutions (average travel time of 8 minutes). The main agricultural systems found in exurban communities are a combination of freshwater aquaculture, irrigated rice crop grown once (22.8% of cropland area on average), twice (19.0% of cropland area on average) and thrice (22.1% of cropland area on average) per year. However, although the total area of land devoted to agriculture is lower than for other clusters (average of 91 ha), the average farm size is 1.07 ha per cultivator.

Rainfed agricultural communities. This cluster represents a total of 2,563 agricultural communities (total population of 2,511,527) mainly located in the south western and northeastern parts of the delta. These communities are characterised by low access to social services (average travel times to secondary schools, hospitals and public offices are respectively 56 minutes,

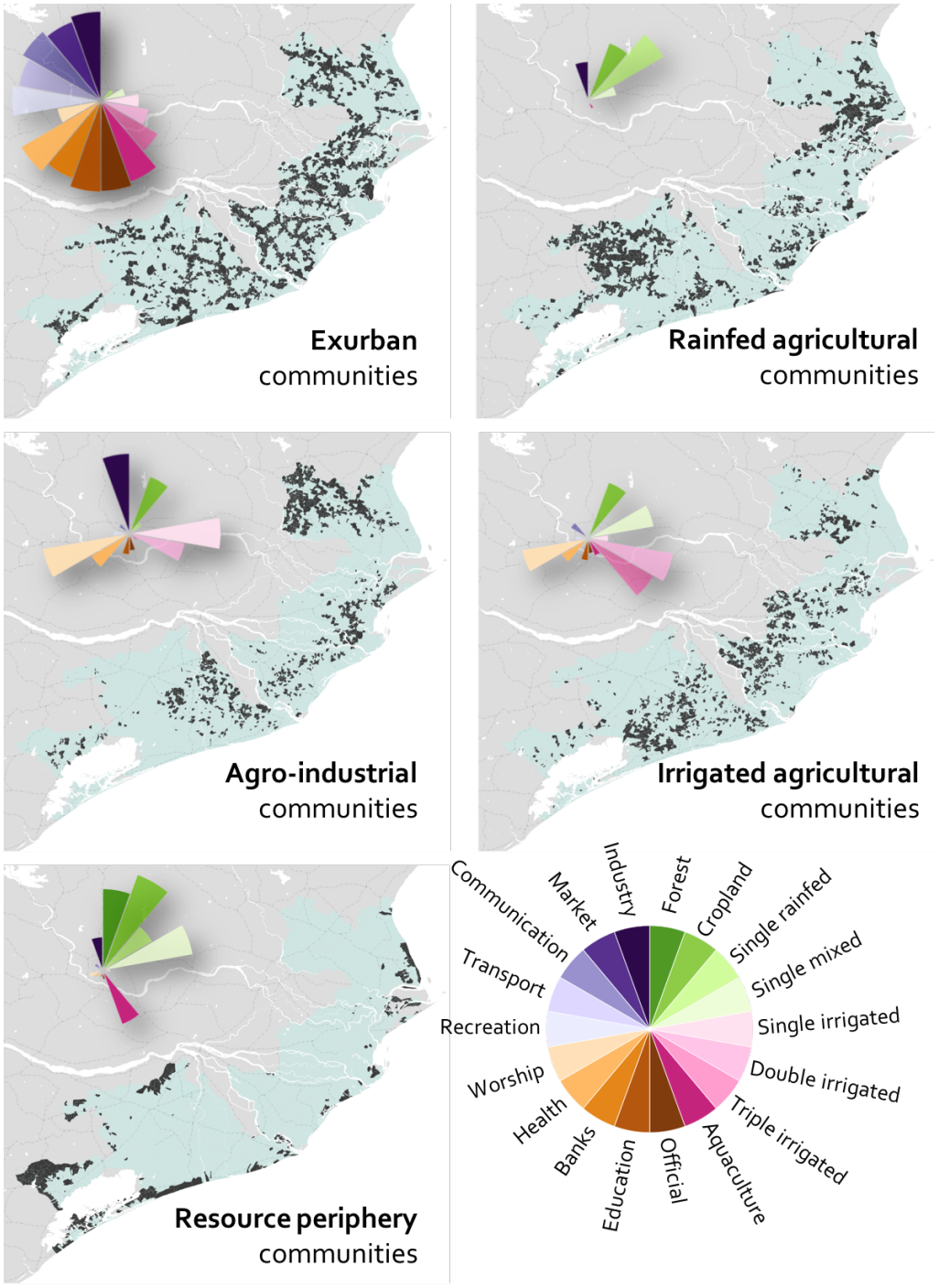


Figure 6.3: Community typologies as identified by model-based clustering. Types of communities were identified based on their access to natural resources, social services and productive infrastructures. Five clusters were identified: communities with great access to productive infrastructures and social services (exurbs), production communities with low agricultural infrastructures (rainfed agricultural) and with irrigation infrastructures (irrigated agricultural), production communities with industries (agroindustrial) and remote communities with high natural resources (resource periphery).

2h14 minutes and 32 minutes) and productive infrastructures, such as markets (travel time of 1 hour and 21 minutes on average) and industries (travel time of 3h03 on average). The main agricultural systems in this cluster are single rice crop (38.3% of cropland area on average)

and single mixed crops (14.6% of cropland area on average), both grown in rainfed conditions. The total cultivated area in each community is 101 ha on average, with an average farm size of 1.00 ha per cultivator.

Agro-industrial communities. The 2,174 communities (total population of 2,122,436) of this cluster are located in the northern part of the delta and in the south of the axis Bhubaneswar-Cuttack. They have a high access to worship amenities, a relatively high access to other social services (average travel times to secondary schools, hospitals and public offices are respectively 51 minutes, 2h05 minutes and 30 minutes) combined with a greater proximity to industrial areas (average travel time of 1h51) and markets (travel time of 1h14 on average) compared to the other agricultural communities. The main agricultural system in this area is irrigated rice crop grown once (36.5% of cropland area on average) or twice (20.0% of cropland area on average) per year. The areas within this cluster are intermediate in terms of occupational type with an average total cultivated area of 97 ha for an average of 0.96 ha per cultivator.

Irrigated agricultural communities. The 2,438 agricultural communities (total population of 2,422,307) of this cluster are located in the central part of the delta and near the Chilika lake. They share similar characteristics with agro-industrial communities in terms of their access to social services (average travel times to secondary schools, hospitals and public offices are respectively 53 minutes, 2h04 and 30 minutes) but with lower access to productive infrastructures (average travel times to markets and industries are respectively 1h17 and 2h57). However, unlike rainfed communities, the irrigated agricultural communities are characterised by a high share of irrigated rice crop grown twice (24.1% of cropland on average) and thrice (23.5% of cropland area on average) per year. The area of cropland is on average 98 ha in total and 0.99 ha per cultivator in the cluster.

Resource periphery communities. Geographically, the 409 resource periphery communities (total population of 362,797) are located in the peripheries of the delta, which are remote areas, far from market towns and urban centres. These communities are characterised by a very low access to social services (average travel times to secondary schools, hospitals and public offices are respectively 1h06, 3h18 and 41 minutes) and to productive infrastructures (average travel time to industries of 4h10 and to markets of 1h40). Due to the lack of irrigation infrastructures in this cluster, the main agricultural systems are single mixed crops (34.7% of cropland area on average) and single rice crop grown in rainfed conditions (26.5% of cropland area on average). The areas within this cluster share a similar occupational structure characterised by the dominance of natural resources, with forest (area of 0.92 ha on average), proximity to aquaculture ponds and a large cropland area with an average of 1.11 ha per cultivator for a total cultivated area of 112 ha on average.

6.4.2 Statistical modelling

Odds ratios were used to quantify the relationships between the response variable (proportion of people engaged in precarious livelihood activities, defined as agricultural labourer and unemployed) and the explanatory variables (livelihood capitals and number of agricultural shocks), controlling for district and population density effects, but also for the effects of class and caste (Table 6.3). An odds ratio above one indicates that, as the explanatory variable increases, the odds of being engaged in precarious livelihood activities for people who are within the legal working age also increase. When explanatory variables are categorical (e.g. "District"), odds are interpreted by comparing the variable level to a reference (district "Bhadrak"). For example, in rainfed agricultural communities, an odds ratio of 0.74 for Jagatsinghpur can be interpreted as: the likelihood of being engaged in precarious livelihood activities for communities located in Jagatsinghpur is 26% lower compared to communities located in Bhadrak.

Results indicated that there was a significant and negative effect of population density on the odds of being engaged in precarious livelihoods only in exurban communities: an increase in population density is associated with a decrease in the odds of being an agricultural labourer or unemployed (OR = 0.94, 95% CI = 0.90, 0.97). It is also apparent that belonging to disadvantaged groups (scheduled castes and tribes) increase the odds of being engaged in precarious livelihoods only in exurban (OR = 1.13, 95% CI = 1.04, 1.22) and agro-industrial communities (OR = 1.14, 95% CI = 1.06, 1.22). Households located in Puri and Jagatsinghpur have lower odds of engaging in precarious activities, when compared to those located in Bhadrak, especially in rainfed agricultural communities (OR_{Puri} = 0.78, 95% CI = 0.72, 0.83; $OR_{Jagatsinghpur}$ = 0.74, 95% CI = 0.69, 0.80).

Table 6.3: Results of the logistic models for each community. The dependent variable represents the odds of engaging in precarious activities (agricultural labourers and unemployed) for people who are within the legal working age. The explanatory variables represent the capitals that households have access to and the number of agricultural shocks that the community faced between 2000 and 2011.

	EXURBAN OR [95% CI]	RAINFED AGRI. OR [95% CI]	AGRO-INDUSTRIAL OR [95% CI]	IRRIGATED AGRI. OR [95% CI]	RESOURCE PERIPH. OR [95% CI]
CONFOUNDERS					
District					
Bhadrak	1.00	1.00	1.00	1.00	1.00
Jagatsinghpur	0.97 [0.89, 1.05]	0.74 [0.69, 0.80] ***	0.77 [0.72, 0.84] ***	0.81 [0.75, 0.88] ***	0.97 [0.77, 1.22]
Kendrapara	0.97 [0.89, 1.04]	0.88 [0.82, 0.95] ***	0.86 [0.80, 0.93] ***	0.89 [0.83, 0.96] **	1.04 [0.85, 1.26]
Khordha	0.90 [0.83, 0.98] *	0.79 [0.73, 0.85] ***	0.83 [0.77, 0.89] ***	0.78 [0.72, 0.85] ***	0.90 [0.74, 1.10]
Puri	0.84 [0.77, 0.90] ***	0.78 [0.72, 0.83] ***	0.74 [0.69, 0.79] ***	0.76 [0.71, 0.82] ***	0.78 [0.65, 0.94] **
Population Density	0.94 [0.90, 0.97] ***	1.02 [0.90, 1.15]	1.05 [0.93, 1.18]	0.94 [0.85, 1.04]	1.05 [0.86, 1.27]
Castes and Tribes	1.13 [1.04, 1.22] **	0.94 [0.88, 1.01]	1.14 [1.06, 1.22] ***	1.05 [0.98, 1.13]	0.95 [0.80, 1.13]
HOUSEHOLD CAPITALS					
Natural	1.11 [1.02, 1.20] *	0.80 [0.64, 0.99] *	0.77 [0.61, 0.95] *	1.03 [0.85, 1.26]	0.81 [0.52, 1.27]
Physical	0.99 [0.96, 1.02]	0.98 [0.96, 1.01]	0.96 [0.94, 0.99] **	1.01 [0.99, 1.04]	1.00 [0.93, 1.07]
Human	0.83 [0.81, 0.85] ***	0.90 [0.88, 0.92] ***	0.93 [0.91, 0.95] ***	0.87 [0.85, 0.89] ***	0.87 [0.82, 0.93] ***
Financial	0.89 [0.87, 0.91] ***	0.93 [0.91, 0.95] ***	0.90 [0.87, 0.92] ***	0.89 [0.86, 0.91] ***	0.92 [0.86, 0.99] *
Social	0.87 [0.85, 0.89] ***	0.92 [0.91, 0.94] ***	1.03 [1.01, 1.05] **	0.99 [0.97, 1.00]	0.94 [0.89, 0.98] **
SHOCKS					
Agri. shocks	0.99 [0.97, 1.01]	1.07 [1.05, 1.09] ***	1.02 [1.00, 1.05]	1.07 [1.05, 1.09] ***	1.08 [1.03, 1.13] **
RANDOM EFFECTS					
Gram Panchayat	1.31 [1.29, 1.34] ***	1.30 [1.28, 1.32] ***	1.30 [1.27, 1.32] ***	1.29 [1.27, 1.31] ***	1.30 [1.24, 1.36] ***

**Indicates a significance level of 0.01 *Indicates a significance level of 0.05

Amongst the five capitals, only human and financial capitals show similar associations across all

clusters: a greater access to them decreases the odds of being engaged in precarious livelihood activities. The effect of human capital is the strongest in exurban communities (OR = 0.83, 95% CI = 0.81, 0.85) and the weakest in agro-industrial communities (OR = 0.93, 95% CI = 0.91, 0.95), while the effect of financial capital is the weakest in remote communities, such as the clusters rainfed agricultural (OR = 0.93, 95% CI = 0.91, 0.95) and resource periphery (OR = 0.92, 95% CI = 0.86, 0.99). The model shows that access to means of transportation and to electricity (physical capital) is associated with lower odds to be engaged in precarious livelihood activities only for households located in agro-industrial communities (OR = 0.96, 95% CI = 0.94, 0.99). The odds of having a precarious livelihood decrease with greater access to natural capital in rainfed agricultural (OR = 0.80, 95% CI = 0.64, 0.99) and agro-industrial (OR = 0.77, 95% CI = 0.61, 0.95) communities, whereas it is the contrary in exurban communities (OR = 1.11, 95% CI = 1.02, 1.20). Social capital was found to be negatively associated with the odds of having a precarious livelihood in exurban (OR = 0.87, 95% CI = 0.85, 0.89), rainfed agricultural (OR = 0.92, 95% CI = 0.91, 0.94) and resource periphery (OR = 0.94, 95% CI = 0.89, 0.98) communities, but positively associated in agro-industrial communities (OR = 1.03, 95% CI = 1.01, 1.05).

The models show that it is more likely that households will engage in precarious livelihood activities when the number of agricultural shocks increases, except for exurban (OR = 0.99, 95% CI = 0.97, 1.01) and agro-industrial communities (OR = 1.02, 95% CI = 1.00, 1.05) where associations between shocks and livelihoods are not significant. Figure 6.4 shows the predicted probability of being engaged in precarious livelihood activities depending on the number of agricultural shocks faced by the community during the ten previous years. These data show that the probability of precarious livelihoods strongly increases with the number of agricultural shocks in agricultural-based communities with low access to productive infrastructures, such as rainfed agricultural, irrigated agricultural and resource periphery. On the contrary, the findings show that the number of agricultural shocks does not have a significant effect on precarious livelihoods in exurban and agro-industrial communities.

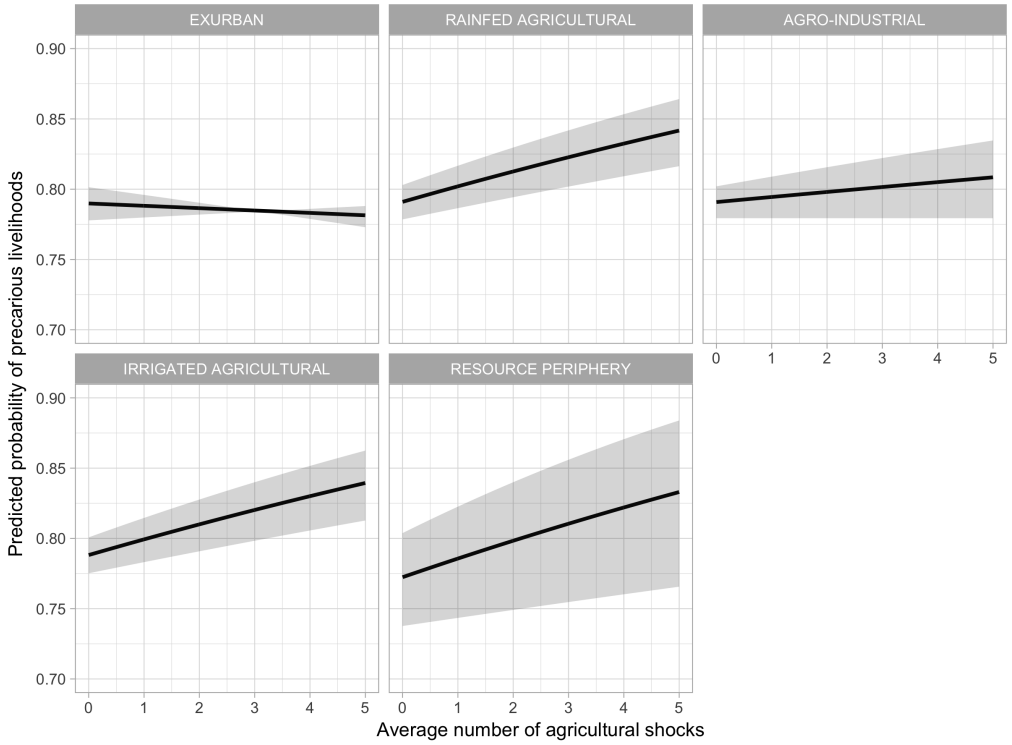


Figure 6.4: Predicted probability of precarious livelihoods conditioned on the average number of agricultural shocks for each community typologies. Based on multiple logistic models (Table 6.3). The range of values in the x-axes are constrained to number of shocks that are likely to be observed in the area over 10 years. The envelope includes the mean plus or minus 1 standard error.

6.5 Discussion

This chapter presents a geographical perspective of livelihood systems and of the impact of agricultural shocks on livelihood activities. The results of this chapter suggest that multiple agricultural shocks increase the probability for households to engage in precarious livelihood activities in most rural communities, except for those located near main roads and productive infrastructures. Another important finding is that access to human capital and to financial capital are associated with more stable livelihoods, such as cultivation, self-employment and salaried employment. Self-employment, defined as household industry work in the census of India (Registrar General and Census Commissioner, 2011), is considered here as a more desirable livelihood compared to agricultural labour and joblessness as it is associated with greater returns to capital and skills (Mandelman and Montes-Rojas, 2009; Gindling and Newhouse, 2014; Falco and Haywood, 2016). The findings also indicate that access to physical capital significantly reduces the likelihood of being engaged in agricultural labour or being unemployed only in agricultural communities with irrigation infrastructures and located near industrial areas (agro-industrial cluster). An increase in natural capital was found to be associated with a decrease in the likelihood of having a precarious livelihood in rainfed agricultural and agro-industrial clusters. Importantly, the findings from this chapter show that this trend is reversed in exurban communities.

6.5.1 Climate change impacts on livelihoods and poverty

The repetition of shocks in agricultural production patterns make people adopt new livelihoods as coping strategies (Olsson et al., 2014; Williams et al., 2016). The findings from this chapter confirm these associations and provide empirical evidence on the impact of multiple shocks on livelihood activities. They further support the idea that multiple climatic stressors lead to the erosion of households' assets (McDowell and Hess, 2012). Households with a strong human capital put in place temporary strategies to cope with the impacts of crop failure, while those with low human capital sell off their assets. For example, households engaged in cultivation would sell off their agricultural land and become agricultural labourers, while households engaged in agricultural labour would become unemployed (Christiaensen et al., 2011; Hall et al., 2015; Singh, 2002). As a result of these dynamics, a large number of households may slide from transient to chronic poverty due to the recurrence of shocks making them unable to rebuild their eroded assets (Ahmed et al., 2009; Hertel et al., 2010). The findings showed no significant associations between agricultural shocks and the likelihood of engaging in precarious livelihood activities in exurban and agro-industrial communities. These results support previous findings in suggesting that investments in infrastructure, such as connections to market centres and social services, provide households with a greater flexibility and agency to cope with climate shocks (Njenga and Davis, 2003; Olsson et al., 2014). Overall, the impact of an increase in the variance of climate will probably lead to a greater variability in agricultural productivity and to a greater number of crop failures (Challinor et al., 2010, 2014). The findings from this study support the idea that such changes are likely to drive households into precarious livelihood strategies, thus exacerbating rural poverty especially in remote rural agricultural communities (Hertel et al., 2010). Although the probability to be an agricultural labourer or unemployed in resource periphery communities is lower than in other clusters in the absence of shocks, it is the cluster where households' livelihoods are the most likely to be negatively impacted by crop failure, probably due to their remoteness and thus to the absence of alternative off-farm livelihood opportunities that could be used as coping strategies. Arguably, the most important result from this research is that rural typologies should be included in the design of climate change assessments to take into account the differential vulnerability of communities to crop failure.

6.5.2 Spatial dimensions of livelihoods

Rural poverty is spatially distributed, with factors such as institutional linkages, access to and control over resources affecting livelihood opportunities (Murray, 2002; Kristjanson et al., 2005; Okwi et al., 2007; Erenstein et al., 2010). Fang et al. (2014) showed that the sensitivity of on-farm and off-farm livelihood strategies to livelihood capitals exhibit different patterns depending on the type of settlement considered. The findings demonstrate that the probability of engaging in precarious livelihoods depends on households' access to capitals, and that the type of community in which households live modifies this association. For example, financial capital has a weaker effect on livelihoods in remote communities than in exurban communities,

natural capital is associated with more precariousness in exurban communities but reduces the likelihood of precarity in single rice crop agricultural systems and physical capital is a determinant only in agro-industrial communities. In remote communities that did not benefit from the technological packages of the green revolution, such as rainfed agricultural and agro-industrial communities, farmers have kept traditional single rice cropping systems (Gumma et al., 2014). In these communities, the findings show that access to natural capital has a positive effect on stable livelihood strategies, notably because of the increased probability to engage in cultivation (Chapter 5). This supports the findings from Watmough et al. (2016) who found that in Assam (India), households living alongside rivers were engaged in vegetable and fruit farming on intensive scales (with 2 to 4 harvests per year), while those further from rivers were engaged in growing a single rice crop per year and had to rely on other forms of income for their livelihoods, such as pensions or government jobs. This finding was also reported by van den Berg (2010) who showed that lack of access to natural resources in rural areas can drive households into more precarious on-farm activities such as daily-wage labour. However, access to natural capital is associated with precarious livelihoods in exurban communities. This finding is likely to be related to the connection of such communities to urban centres: proximity to market increases the pressure on farm holdings, encourages smallholders' land dispossession and thus leads to the cornering of natural resources by a few large-scale farmers (Birthal et al., 2013; Manjunatha et al., 2013). Previous research has demonstrated that a larger average of cropland per household was associated with fewer large-scale farms owning the natural resources (Levien, 2013). This hypothesis is further supported by the descriptive statistics presented earlier, showing that the area of cropland per cultivator in exurban communities is amongst the largest of all clusters, despite having the lowest average of cropland area. It shows that smallholders in exurban communities are more likely to be driven out of agriculture than in the other types of rural communities.

The findings show that access to human and financial capitals has a positive effect on the probability of engaging in stable livelihood strategies. Access to financial services and workforce availability enable households to decrease the barrier to engage in more remunerative on-farm activities, but also to engage in off-farm livelihood strategies (Jansen et al., 2006; Babulo et al., 2008; Jiao et al., 2017). The typology of rural communities shows that the effect of financial capitals is weaker in remote communities with rainfed agricultural systems (rainfed agricultural, resource periphery). These differences can be explained in part by the physical lack of access to job opportunities in remote communities: although access to financial services helps households to decrease the barrier to engage in stable activities, the lack of livelihood opportunities reduces the positive impact of access to financial capital (Zenteno et al., 2013). The findings show that access to physical capital reduces the probability of engaging in precarious activities, but only in agro-industrial communities. This result highlights the link between physical capital and off-farm strategies: private means of transportation enable households to reach more livelihood opportunities (Njenga and Davis, 2003). The cluster analysis showed that agro-industrial communities are characterised by their proximity to industrial areas, which explains why access to physical capital has a significant effect on livelihoods in these communities only.

The results from this chapter also show that the overarching influence of social and cultural norms on lowest castes's access to decent employment depends on the proximity to productive infrastructures and markets. People who belong to disadvantaged groups are more likely to be engaged in precarious labour in exurban and agro-industrial communities, confirming that people with higher caste status have better endowments required for absorption in the non-farm market (Chandrasekhar and Mitra, 2018). On the contrary, it appears that the effect of caste is not the most significant driver to explain the causes of precarious livelihoods in more remote communities. This surprising result can be explained by the prevalence of culturally homogeneous communities in Odisha's remote areas, thus reducing its influence on access to land ownership and assets (Lakerveld et al., 2015).

Overall, the findings demonstrate that conducting place-based analyses of the determinants of livelihood strategies is necessary to design effective policies for poverty alleviation and rural development. Community typologies based on participatory selected key indicators are an effective way to implement such analyses in order to highlight the different drivers of precarity within the landscape.

6.6 Conclusion

This chapter makes several contributions to answering the research aim and more specifically Objectives 3 and 4. First, it defined a set of indicators that adequately capture the multi-dimensional and multi-attribute nature of rural communities and household capitals. Two different methods were used to obtain the final results: a deductive binning of indicators into different categories based on rapid rural appraisals, followed by an inductive indicator method constructed via model-based clustering for community typologies and via principal components analysis for household capitals.

Second, the community typologies show a distinct spatial pattern, highlighting a profile of rural communities with similar bundles of capitals. It was demonstrated that the type of rural community in which households live modifies the associations between livelihood capitals and precarious livelihoods. Access to physical capital reduces the likelihood of being engaged in precarious activities only in communities located near industrial areas, where people can find alternative livelihood opportunities. In rural communities, access to natural capital has a positive effect on stable livelihood strategies, notably because of the increased probability to engage in cultivation, while it has a negative effect in exurban communities, showing that smallholders in these places are more likely to be driven out of agriculture than in the other agricultural communities. The results from this chapter also demonstrate that lack of access to financial services and workforce unavailability prevent households to profit by local job opportunities that would enable them to engage in more sustainable livelihoods. Finally, people who belong to disadvantaged groups are more likely to be engaged in precarious labour in exurban and agro-industrial communities, confirming that people with higher caste status have better endowments required for absorption in the off-farm market and for land-ownership

where agricultural land is scarce.

Third, the chapter demonstrated quantitatively that the type of rural community in which households live modifies households' opportunities for coping strategies. The findings show that recurrent climatic shocks are a driver of precarious livelihoods, except in exurban and agro-industrial communities where the number of crop failures faced by the community does not influence livelihood opportunities. This result is explained by the availability of off-farm livelihood opportunities in well-connected communities: households can engage in off-farm daily wage activities as a coping strategy, preventing them to sell their productive assets and thus to become agricultural labourers or unemployed.

A final caveat is that this chapter did not address the persistent difficulty in characterising the causal drivers of poverty nor in quantifying livelihood dynamics in the long-term, including questions of asset trade-off and migration. Nevertheless, such a quantitative analysis has a wider application for rural development policies seeking to make livelihoods more resilient to climate hazards and to reduce poverty. Identifying typologies of rural communities is useful for assessing needs and targeting intervention or mitigation programs. It provides an approach for policy makers to take into account the contextual factors that drive livelihood precarity and thus to target more strategically anti-poverty programmes to maximise their effect rather than equally distributing them across all places. Interventions should focus on strengthening human and physical capitals in well-connected communities to ensure that households are able to diversify their livelihoods to off-farm strategies, while they should be targeted on providing financial capital and complementary livelihood opportunities during lean season in remote areas.

CHAPTER 7 Synthesis

The main determinants of livelihood strategies are related to the influence of inherited social-economic stratification and power relationships, defined by gender, age, wealth, ethnicity, class and caste. However, very little is known about the geographies of rural livelihood precarity over a large spatial extent and no previous studies have investigated if access to household capitals and community resources are significant determinant of precarious livelihoods. Understanding if there is a significant influence of place, access to capitals and climatic stressors on rural livelihoods can enrich our understanding of the drivers of rural poverty in India, which is central to achieving sustainable development pathways in agrarian societies. This chapter compiles and synthesises the findings from the previous chapters to address the following research objectives: (i) to characterise the components of livelihood capitals that are associated with livelihood opportunities; (ii) to characterise the influence of livelihood capitals on precarious livelihoods; (iii) to characterise the influence of climatic stressors on precarious livelihoods; and (iv) to characterise how place influences the determinants of livelihood precariousness. It also provides an overview of the main contributions of this thesis to the field of rural and livelihood studies. The chapter then discusses the wider significance of this research, before presenting its main limitations. After suggesting opportunities for future work, the last section presents the main conclusions of this thesis by answering its overarching aim, which was to characterise the determinants of precarious livelihoods in the Mahanadi Delta.

Results and conclusions from this chapter were partially presented at the ESRC conference "Innovation" in Southampton (UK), December 2017, at the FAO Expert Workshop on Socio-Ecological Systems in Rome (Italy), January 2018 and at the AAG Conference in New Orleans (USA), April 2018.

7.1 Research findings

The following section presents a synthesis of the research conducted in this thesis. It summarises the key findings and presents how they address the research objectives (Table 1.2, page 12) in order to answer the overarching research aim of this thesis.

7.1.1 Components of livelihood capitals associated with livelihood opportunities

Until now, the majority of studies seeking to apply the sustainable livelihoods approach have mainly focused either on household-level capitals (e.g. Fang et al., 2014), on aggregated proxies of community capitals at the district or provincial level (e.g. Donohue and Biggs, 2015) or have conflated both household and community capitals together (e.g. Paudel Khatiwada et al., 2017). Although they have provided useful insights about the factors that might influence rural livelihoods, they do not differentiate common-pool resources (community capitals) from private goods (household capitals), while these two types of goods do not operate under the same level of management (Cutter et al., 2014). The sustainable livelihoods framework in general and these studies in particular are therefore limited, as they do not account for the issues of access to public services that have emerged in current debates on rural development (Flora et al., 2015). The findings from this thesis argue that particular attention should be paid to the importance of community capitals as assets through which people are able to widen their access to resources and to other actors. In particular, rural studies using conceptual frameworks such as the sustainable livelihoods framework need to consider the multilevel factors that might affect households' livelihoods (Bebbington, 1999; Gutierrez-Montes et al., 2009): (i) the place in which people live and especially their access to three types of community capital asset; (ii) people's access to five types of household capital asset; (iii) the ways in which they combine and transform private assets using community assets in the building of livelihoods that meet their material and experiential needs as far as possible; (iv) the ways in which those assets are associated with each other, in particular their synergies or trade-offs; (v) the ways in which people are able to expand their asset-base through engaging with other actors through relationships facilitated by common-pool resources and governed by the logics of the state, market and civil society; and (vi) the ways in which they are able to deploy and enhance their capabilities both to make living more meaningful and to change the dominant rules and relationships governing the ways in which resources are controlled, distributed and transformed in society.

In light of the first research objective of this thesis, which was "to characterise the components of livelihoods capitals associated with livelihood opportunities", Figure 7.1 provides a conceptual theoretical framework based on the sustainable livelihoods framework (Scoones, 2015) and on the livelihood strategy framework (Nielsen et al., 2013). Both frameworks are combined and expanded through the findings from this thesis and the literature, especially the nested multi-scale spatial hierarchy of agricultural landscapes (Lyle, 2015). By drawing on the framework proposed by Scoones (1998) with the "blackbox" of institutions, organisations and policy and

based upon the work of Ribot and Peluso (2003), the role of institutions and organisation is included within the "capitals" section rather than a separate box as they are inherent to the household's access to resources, and to avoid giving them a superficial nod, as it was mentioned by Scoones (2015). As a consequence, processes that determine access to resources are discussed in this section, such as politics of inter- and intra- household relations, systems of power (e.g. age, gender, class, caste, wealth) and community factors (e.g. ethnicity balance in the community, clubs). The four vertical shaded boxes in the framework are at the centre of livelihoods approaches: households follow a pathway by taking advantage of resources through different livelihood activities to achieve outcomes, this system being influenced by the context, trends and shocks. The different livelihood capitals that have been used in the literature (see Chapter 2) or mentioned during the rapid rural appraisals (see Chapter 3) are grouped into three main components: environmental conditions, community capitals and household capitals. They were then subdivided based on the literature and on the findings from Chapter 4.

7.1.1.1 Context

When considering livelihoods, there are multiple factors that constrain or enable people's actions (Batterbury, 2008). The connections between "context" and the rest of the framework are all-encompassing. Wider structures and politics are central to the understanding of livelihoods and the framework focuses on the external conditions (natural context, infrastructures and systems of power) that have an influence on households' access to resources.

Natural conditions. Topography combined with agro-meteorological characteristics (rainfall, temperature and soil type) have an influence on the proneness of the land to natural hazards, the type of crop, the number of cropping seasons that is possible to cultivate and on the potential maximum yield that one can expect from the land. Yields are lower in higher lands and it is unlikely to have two cropping seasons due to water scarcity, while low and very low lands are prone to water logging.

Physical conditions. Having access to all-weather transportation infrastructures (roads) improve working opportunities, access to marketing outlets (traders are able to come to buy goods directly in the community) and to health services (ambulances are able to come). Road connectivity is a key driver of livelihoods and has been considered as a household physical capital in several livelihood studies. However, this thesis argues that road is not a resource per se, but rather a contextual factor that will condition households' access to resources, thus it should be considered as part of the context. Moreover, it appears important to mention that road connectivity is still reflected in the community-level capitals through the cost-surface analysis of physical access to services and markets.

Systems of power. The main determinant of livelihood strategies that influences and conditions households' access to resources is the socio-economic group to which its members belong, defined by gender, age, wealth, ethnicity, class and caste. These factors play a major role for the household's power relationships and social networks by removing (or creating) barriers to their

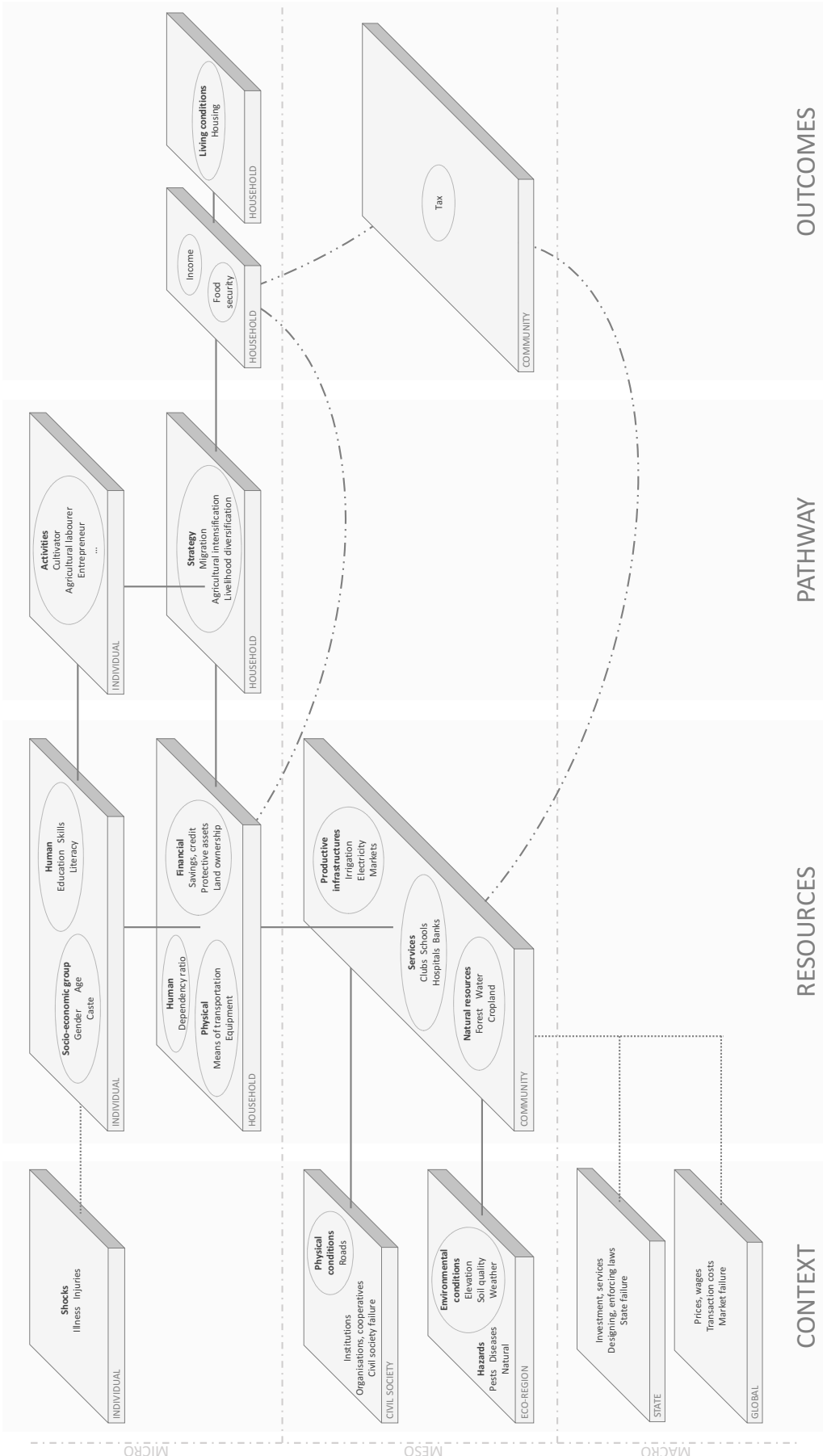


Figure 7.1: Multilevel livelihoods framework. The four vertical shaded boxes in the framework are at the centre of livelihood approaches: households follow a pathway by taking advantage of resources through different livelihood activities to achieve outcomes, this system being influenced by the context, trends and shocks.

use of livelihood assets. The socioeconomic hierarchy conceptualised by gender, class and caste is linked to ownership and income and plays a significant dimension in access to assets and to the type of activities conducted by people. Disadvantaged caste members can suffer from social and economic exclusion, women can suffer from a lack of access to certain types of assets or from a social unacceptability to undertake some activities, and age will have an influence on the member's employment opportunities. Moreover, status employment is dominated by upper caste, while physical labour and low status jobs are mostly performed by lower caste or dalit. As a consequence, income disparity, employment opportunities and access to capitals are highly associated with the systems of power, and especially with the caste system.

7.1.1.2 Community capitals

Rural communities have resources within them, which are considered as capitals when households use them to achieve their livelihoods (Flora et al., 2015). Based on the associations between community capitals demonstrated in Chapter 4, they can be grouped into three main categories: natural resources, access to services and productive infrastructures.

Natural resources. Different natural resources were raised by communities as determinant for pursuing their livelihood strategy: (i) access to open water resources; (ii) access to forest; and (iii) access to cropland. Although access to natural resources (for example to a forest) can be mitigated by social relations of class and caste, the findings from this thesis showed that they were still considered as determinants of livelihood opportunities. Proximity to a lake, a river or the sea gives them the opportunity to diversify their livelihood activities and their source of food through fishing or kitchen gardening (through manual irrigation). Concerning forest resources, different products can be traded, such as timber (e.g. wood, charcoal) and non-timber forest products (e.g. bamboo, seeds, leaves and flowers). The number of acres available at the community level was found to condition households' choice of a livelihood strategy. Although access to agricultural land is part of one household's factors of production, the area of cropland cultivated at the community level leads to synergies for agricultural marketing, social networking and employment.

Access to services. Proximity to financial services was highlighted by the communities as an important factor, for the main reasons that it facilitates the collection of state schemes and pensions and that distance increases barriers to have access to savings and loans. Although physical access to banks does not guarantee access to financial services, it increases the likelihood for households to get bank loans to invest in their means of production (agriculture or other income-generating activities) and prevents them to rely on local moneylenders to cope with external shocks, thus reducing the likelihood of distress migration, such a strategy being put in place to get fast cash or to reimburse debts. Availability of social clubs at the community level, such as financial groups (such as tontines in Africa or self-help groups in India), youth and farmers groups, gives a greater possibility of kinship ties and have an influence on livelihood strategies pursued as they can be a lever for the development of income-generating activities. Finally, access to sanitation facilities (latrines, drinking water) and to health facilities (health

centre, hospital) conditions the labour capacity of individuals by reducing their risk of getting health problems, while proximity to education infrastructures enables individuals to improve their skills and abilities, thus improving households' human capital.

Productive infrastructures. Irrigation facilities play a major role into mitigating the effects of climate variability (droughts or floods) on agricultural production. Households' access to irrigated land is mainly conditioned by the availability of irrigation facilities at the community level and the community's supply of electricity. Based on this thesis' case study, irrigated land is considered as a community capital because irrigation infrastructures in Odisha were built by the Government under the "Green Revolution scheme and access to them is available to all dwellers. Households' access to irrigated land is thus conditioned by the availability of irrigation facilities at the community level and to their capacity to use this resource is conditioned by their access to electricity. Availability of electricity at the community level is also a lever for livelihood diversification through the development of household enterprises (agricultural transformation, handicraft production). The proximity to a marketing outlet, such as all-purpose markets, cooperatives or societies, is one of the key determinants to develop income-generating activities and acts as a catalyst for livelihood diversification (employment opportunities) or agricultural intensification (outlet for agricultural production).

7.1.1.3 Household capitals

Household capitals are defined as "the assets households have access to but also what they believe, feel and identify with" (Bebbington, 1999). However, the framework presented here simplifies it by mainly considering elements that can be quantified. Although this approach leads to a simplification of the view of what assets are (vehicles for instrumental, hermeneutic and emancipatory action), it appears relevant to consider such a quantitative approach to upscale livelihood studies and make them usable in a more nuanced way by wider institutional structures through the use of mixed-methods. The framework presented here does not use the version of the five capitals presented by Carney (1998) in order to move away from the assumption that they are economic units.

Productive assets. At the household level, access to productive assets (factors of production or physical capital), such as machinery (tractor with plow, water-pump, fishing boats, sewing machine), tools and equipment (draft animals, seeds, fertilisers) enables households to increase their agricultural or fishing productivity or diversify their activities, thus earning incomes. Means of transportation (bicycle, motorcycle, car) allow households to look for new outlets for their production and also increase their access to community services (hospitals, banks, schools) by reducing travel times. Finally, the size of cropland available (considered as natural or physical capital in the literature) and its ownership status is a determining factor for livelihood strategies, as it will be the main factor influencing the potential incomes and food supply that one household can expect from cultivating this land.

Financial capital. Households' financial capital includes savings, formal and informal credits,

remittances, pensions, insurances and any protective asset that is held as a store of value and that can be sold if the household faces an external shock (crop failure, death, disease, wedding). Protective assets include cash, jewellery and small livestock (if the household is not involved into livestock rearing). Overall, households' level of indebtedness should also be considered in the assessment of financial capital, as it can turn financial capital into a negative asset when the debt-to-capital ratio is greater than one.

Human capital. The overall number of active members (or labour force) in the household also has a great influence on the range of livelihood activities that households can put in place. A great number of members will allow one household to cope faster in the case of an external shock, as all members can look for income-generating activities (mainly daily-wage labour). Closely related to the number of active members is the household's dependency ratio, which is defined as the number of dependent individuals to the total number of household members. Household members' health status is also important, because it determines the capacity of individuals to apply their capabilities to achieve livelihood activities, and so is their level of education and skills, as educated and skilled members are more likely to diversify the range of livelihood activities undertaken by one household.

7.1.1.4 Spatial distribution, synergies and trade-offs

Few studies have looked at the spatial distribution of livelihoods or at the associations that exist between livelihood capitals (see Chapter 2). However, understanding the spatial patterns of asset endowment and how they might be associated with each others should not be overlooked as it provides a multidimensional and coherent approach to improving households' access to livelihood assets, which are seen as the main determinants of household-level risk-management capacity (Jakobsen, 2013).

This thesis showed that community capitals are not randomly spatially distributed and they appear to follow a gradient based on the proximity/remoteness of communities to the main trading centres and axes of communication. Remote communities have a lower access to services (hospitals, schools, banks) and to productive infrastructures (irrigation, markets) but a greater access to natural resources than well-connected communities. It highlights a trade-off between natural resources and public infrastructures, confirming findings from previous studies (e.g. Turner et al. 2014).

The spatial distribution of household capitals is also associated with location: households who live in communities close to the main trading centres (with access to services and productive infrastructures) have a greater access to factors of production (physical and natural capital) and financial capital than households located in remote communities. It is interesting to highlight that although community natural resources decrease with proximity to rural centres, the average farm size increases, suggesting agricultural land ownership transformation from smallholders to large-scale farmers. It also appears that there is a trade-off between labour force and deprived socio-demographic groups on the one hand (in remote areas) and factors of production and

financial capital on the other hand (near rural centres). This spatial trade-off suggests that access to productive infrastructures near trading centres is likely to be associated with land-grabbing and thus migration, leading to the loss of labour force at the household-level.

7.1.2 Influence of livelihood capitals on precarious livelihoods

Belonging to disadvantaged socio-economic classes, such as scheduled castes and tribes, leads to weaker kinship ties and was found to increase households' likelihood to engage in precarious agricultural livelihoods, a result which mirrors the issues of power that still exist in India regarding socially excluded groups, especially lower castes who suffer from land market exclusion and lack of employment opportunities. Gender also has a strong influence on livelihood opportunities, with women being excluded from inheritance patterns, thus jeopardising their livelihood opportunities. Men are able to access the better paid, non-farm jobs, while leaving women behind to manage agricultural production, leading to hidden forms of livelihood precarity (Rao, 2006). Such systems of power lead to a differential access of households to assets both at the household and community levels, which contributes to their resilience to social, economic and environmental stresses (Chambers and Conway, 1991; Ellis, 2000b) and modify their ability to benefit from the livelihood opportunities available to them. This thesis confirmed the predominant role of mediating factors (social status, relations and institutions) into perpetuating poverty and showed that they are the most significant predictor of livelihood precarity. However, the findings from this thesis also showed that there are other determinants of precarious livelihoods, such as access to household and community capitals. This section summarises such findings by showing the influence of household and community capitals on the susceptibility of communities to landless agricultural labour, an indicator of chronic poverty.

7.1.2.1 Influence of community capitals

Community capitals, such as natural resources, distance to services and to productive infrastructures are significant components of rural livelihoods and this thesis demonstrated that they have an influence on households' livelihood opportunities and on their likelihood to engage in precarious livelihoods (see also Chapter 5).

Influence of natural resources. Households located in communities that have a greater access to natural resources (usually associated with remote areas) are less likely to engage in precarious agricultural livelihoods such as agricultural labour. A greater access to common-pool natural resources enables a greater number of households to engage in cultivation, reducing their likelihood to engage in precarious activities (de Sherbinin et al., 2008). Moreover, as villages located in remote areas are usually tribal communities who share institutions of kinship in relation to land, farms remain in the extended family, which reduces the likelihood to engage in daily-wage agricultural labour (Mosse et al., 2002). Access to natural resources also allows households to diversify their livelihoods (through fishing or picking of non-timber forest products), improving

their ability to cope with economic and environmental shocks (Barrett et al., 2001; Liu et al., 2008; Gautam and Andersen, 2016). As a consequence, although previous research has shown that access to natural resources can been associated with greater levels of poverty in India (c.f. Watmough et al., 2016), this thesis shows that access to common natural resources leads to more stable agricultural livelihoods.

Influence of productive infrastructures. Proximity to markets and industrial areas is associated with external investments that increase pressure on farm holdings, thus encouraging smallholders' land dispossession by larger farm holders (Birthal et al., 2013; Levien, 2013). As a consequence, this leads to an increase of the likelihood to become agricultural labourer for smallholder households who are located in these communities. This thesis also shows that access to productive infrastructures is associated with smaller farm holdings who cannot provide a stable source of agricultural employment, thus reducing the need for agricultural labour and reducing the likelihood of being hired throughout the year.

Influence of access to services. The findings from this thesis do not identify any significant association between proximity to education and health facilities and agricultural livelihoods, which might be related to their relatively homogeneous distribution across the delta. Moreover, it is thought that the impact of such services on households and livelihoods should only be visible in the long-term, which was not accounted for in this thesis (Okwi et al., 2007). Although participants flagged proximity to financial services as an important asset for their livelihoods, the quantitative analysis shows that proximity to financial institutions goes hand in hand with a greater proportion of landless agricultural labourers due to smallholders' land dispossession. The issue that emerges from these findings is that physical proximity to financial infrastructures is not associated with access to financial services, and that efforts should focus on reducing institutional barriers to rural finance in priority. The availability of recreational facilities (e.g. cinemas, stadiums, playgrounds) and of unions gives a greater possibility of kinship ties, which goes hand in hand with people's participation in such groups (Krishna and Uphoff, 1999; Soltani et al., 2012), leading to an increase in the proportion of marginal labourers in order to develop income-generating for the future, through collective action (Datta, 2015).

7.1.2.2 Influence of household capitals

Previous studies have indicated that several household capitals, constrain or influence choices of livelihood strategies (Scoones, 2009; Nielsen et al., 2013; Fang et al., 2014). Education, physical assets and access to infrastructure were found to be the main factors enabling households to access more remunerative strategies (Jiao et al., 2017). Ownership of productive assets and the absence of financial liquidity were found to be a barrier to access more remunerative strategies, making upward mobility difficult for poor households without capital to invest (Barrett et al., 2006). Fang et al. (2014) showed that natural and human capitals were positively correlated with on-farm livelihood strategies, while financial and social capitals were the catalyst for driving non-farm activities. This section sheds new lights on this body of literature by synthesising

the findings from this thesis in regards to the influence of household capitals on agricultural livelihood precarity (see also Chapter 5).

Influence of productive assets. Access to a large farm area (including cropland, tree plantation and pasture) is negatively associated with precarious labour. This thesis also found that access to private means of transportation and to electricity reduces the likelihood to engage in precarious labour, as it enables households to reach marketing outlets to sell their agricultural products or to buy agricultural inputs (leading to more stable forms of agricultural livelihoods) and to operate motor pumps for irrigation, enabling them to get extra income through the cultivation of vegetable gardens and thus to remain as cultivators.

Influence of human capital. A strong human capital enables households to be more resilient to climatic shocks by looking for temporary income-generating activities after facing an external shock, thus preventing them from selling their land and engaging in agricultural labour. For example, households with more than two working age members are able to send one to look for daily-wage work while the other look after the farm when they need cash. It also increases the availability of workforce during peak times of labour (e.g. crop establishment and harvest), reducing the need for extra labour costs.

Influence of financial capital. Access to financial capital enables households to reduce the barriers to retaining a remunerative on-farm livelihood strategy such as cultivation, thus reducing the likelihood for households to engage in agricultural labour. Actually, access to financial services and ownership of protective equipment (assets that can be sold if the household faces a shock) enable households to cope with crop failure, thus preventing them to sell their land after facing a shock. Therefore, households that lack access to financial capital are more likely to sell their productive assets, thus engaging in agricultural labour. It is important to notice that although debt was not included in the quantification of financial capital in this thesis, it plays a significant role in determining livelihood strategies. For example, Chapter 3 showed that households who are indebted to agricultural traders have to send one of their members for unpaid labour migration to repay their debt, thus undermining their human capital.

7.1.3 Influence of climatic stressors on precarious livelihoods

This thesis provides empirical evidence that the repetition of shocks in agricultural production patterns leads to the erosion of households' assets and makes its members adopt new livelihoods as coping or adaptation strategies. Households with a strong human capital put in place temporary strategies to cope with the impacts of crop failure, while those with low human capital sell off their assets (such as agricultural land for households who own land) or stop fulfilling their lease obligations (for households engaged in agricultural labour). As a result of the erosion of their assets, households have to engage in more precarious forms of livelihoods; for example from cultivation to agricultural labour or from agricultural labour to unemployment, leading to a large number of households sliding from transient to chronic poverty. The repetition of shocks catalyses these dynamics by making households unable to rebuild their eroded assets

between shocks (Wisner et al., 2004; Ahmed et al., 2009; McDowell and Hess, 2012). The impact of an increase in the variance of climate will probably lead to a greater variability in agricultural productivity and to a greater number of crop failures (Challinor et al., 2010, 2014). Such changes are likely to drive households into more precarious forms of livelihoods, thus exacerbating rural poverty in the long-term.

7.1.4 Influence of place on livelihood precarity

This thesis shows that typologies of rural communities can be identified, based on their access to bundles of community capitals: access to productive infrastructures (markets, agricultural outlets, industrial facilities), natural resources (forest, open-water, total cropland area) and social services (education and health facilities, financial institutions). When mapped, the community typologies exhibit distinct spatial patterns, mainly driven by their main agricultural systems and their degree of remoteness. The findings also show that rural population density has a major influence on the social and demographic aspects of rural communities, but also on livelihood opportunities. Agricultural households are more likely to engage in precarious activities in highly populated communities, due to the increased pressure on farm holdings in these areas that encourages smallholders' land dispossession by larger farm holders, forcing the newly landless agricultural households to work as agricultural labourers for the larger farmers.

The thesis demonstrates that engaging in precarious livelihoods depends on households' access to capitals, and that the sensitivity of precarious livelihood strategies to livelihood capitals shows different patterns depending on the type of community considered. Access to physical capital reduces the likelihood of being engaged in precarious activities only in communities located near industrial areas, where people can find alternative livelihood opportunities. Access to natural capital has a positive effect on stable livelihood strategies, notably because of the increased probability to engage in cultivation, while it has a negative effect in exurban communities, showing that smallholders in these places are more likely to be driven out of agriculture than in the other profiles of agricultural communities. This thesis also demonstrates that lack of access to financial services and workforce unavailability prevent households to profit by local job opportunities that would enable them to engage in more sustainable livelihoods.

The results from this thesis also show that the overarching influence of social and cultural norms on lowest castes's access to decent employment depends on the proximity to productive infrastructures and markets. People who belong to disadvantaged groups are more likely to be engaged in precarious labour in exurban and agro-industrial communities, showing that people with higher caste status have better endowments required for absorption in the non-farm market. On the contrary, it appears that the effect of caste is not as significant in more remote communities, which can be explained by the prevalence of culturally homogeneous communities in Odisha's remote areas, thus reducing the influence of socio-economic groups on access to land ownership and assets.

Moreover, the type of rural community in which households live modifies households' oppor-

tunities for coping strategies. Recurrent climatic shocks are a driver of precarious livelihoods, except in exurban and agro-industrial communities where the number of crop failures faced by the community does not influence livelihood opportunities. This is explained by the availability of off-farm livelihood opportunities in well-connected communities: households can engage in off-farm daily wage activities as a coping strategy, preventing them to sell their productive assets and thus to become agricultural labourers or unemployed.

7.2 Wider significance

In addressing the research objectives, the findings of this thesis corroborate findings from previous studies but also contribute to the generation of new knowledge that provide theoretical and methodological contributions to the existing literature. Moreover, several findings are relevant to the public policies that were identified in the literature review (Chapter 2). This section discusses the main theoretical and methodological contributions emerging from this thesis (summarised in Table 7.1) and outlines how the findings feed into concrete policy recommendations.

Table 7.1: Summary of the key findings of this thesis. Only the key findings are presented in order to show the generation of new knowledge and corroboration with the literature arising from this thesis. The findings are grouped according to the research objectives.

Corroboration with the literature	Key contributions to the generation of new knowledge
OBJECTIVE 1	
► Importance of differentiating private goods from common-pool resources (Lindenberg, 2002) ► There is a trade-off between natural resources and public infrastructures (Turner et al., 2014)	► Inclusion of community capitals in a Multilevel Livelihoods Framework (**theoretical contribution**) ► Household and community capitals follow a spatial gradient based on the proximity/remoteness of their location to the main axes of communication (**empirical contribution**)
OBJECTIVE 2	
► Financial and social capitals are the catalyst for driving non-farm activities (Fang et al., 2014) ► Common natural resources and access to infrastructures influence households' access to livelihood opportunities (Jiao et al., 2017)	► Households that lack access to financial capital are more likely to sell their productive assets and engage in precarious livelihood activities (**empirical contribution**) ► Access to infrastructures encourages smallholders' land dispossession by larger farm holders, thus increasing the likelihood for households to engage in precarious on-farm livelihoods (**empirical contribution**)
OBJECTIVE 3	
► The repetition of shocks in agricultural production patterns make people adopt new livelihoods as coping strategies (Olsson et al., 2014)	► Households with a strong human capital put in place temporary strategies to cope with the impacts of crop failure, while those with low human capital sell off their assets, such as agricultural land for households who own land, or stop fulfilling their lease obligations for households engaged in agricultural labour (**empirical contribution**)
OBJECTIVE 4	
► The investigation of place tells us that vulnerability and livelihood opportunities are variable and situational (Chen and Lopez-Carr, 2015)	► There are typologies of rural communities based on their access to bundles of community capitals (**methodological contribution**) ► Access to natural capital has a positive effect on stable livelihood strategies except in exurban communities where it has a negative effect (**empirical contribution**) ► The influence of socio-cultural norms on access to decent employment depends on the proximity to productive infrastructures and markets (**empirical contribution**) ► Recurrent climatic shocks drive precarious livelihoods except in exurban communities (**empirical contribution**)

7.2.1 Theoretical implications for livelihood perspectives

Altogether, the theoretical contribution of this thesis to the literature on livelihood perspectives gravitates around the question of scale in relation to livelihoods. This thesis provides empirical evidence for the role of community capitals in determining rural livelihood opportunities. To date, the literature lacks with regard to studies that investigate the questions of scale in relation to resource governance and livelihood opportunities. Livelihood perspectives enable an analysis of what people have rather than focusing on what they do not, although they also recognise constraints on livelihood strategies and outcomes. They encourage a more holistic analysis of people's lives, responding to the complexity of how resources may be accessed and benefited from, the diversity of relationships and the range of perspectives and attitudes that people have about their own lives and aspirations. However, they do not address key lacunae that have been raised in recent discussions, including questions of knowledge, politics, scale and dynamics (Scoones, 2009). More specifically, they tend to overlook the importance of place and scale, wether temporal or spatial, on influencing people's livelihoods. When livelihood capitals and activities are investigated within determined levels and spaces as it has been the case in most of the literature so far, important connections are missed. A holistic approach to livelihoods needs to pay attention to cross-, multi-level and scale interactions and to the way structures and institutions are nested within broader arrangements. There is an increasing importance of looking at linking solid, place-based analysis with broader scales, including trans-national connections, where the global and the local are not separated analytically, but rather intertwined through connections, relations and dynamics between diverse locales (Batterbury, 2008; Scoones, 2009). By characterising the role of community capitals on agricultural livelihoods and by exploring the role of place on the geographies of livelihood precariousness, this thesis contributes to the recognition of cross-scale dynamic change and thus to the current discussion about re-energising livelihood perspectives.

7.2.2 Methodological contributions and reproducibility

Investigating the impacts of climate change on rural livelihoods and rural poverty is a continuing concern amongst academics from environmental sciences and development studies, but also amongst practitioners working in the fields of rural development. The complexities of rural poverty need to be examined at both individual and collective levels, requiring a multidimensional approach to the issues of livelihood precarity. In order to understand how and why rural households implement selected strategies to increase their well-being or to cope with shocks in a given environment, it is necessary to use a holistic approach. Therefore, conducting place-based analyses of the determinants of livelihoods and poverty is necessary to design effective policies for poverty alleviation and rural development. This thesis provides new methodological insights for profiling rural communities and for understanding the relationships between place and livelihoods by highlighting the different drivers of precarity within the landscape.

The broad components of this thesis' methodological contributions include: identifying indica-

tors through mixed qualitative and quantitative methods; and building aggregated proxies to quantify livelihood assets and profiling rural communities. The thesis defined a set of indicators that adequately capture the multi-dimensional and multi-attribute nature of rural communities and household capitals. Two different methods were used to obtain the final results: a deductive binning of indicators into different categories based on rapid rural appraisals, followed by an inductive indicator method constructed via model-based clustering for community typologies and via principal components analysis for household capitals. Overall, identifying typologies of rural communities is useful for assessing needs and targeting intervention or mitigation programs. It provides an approach for practitioners and policy-makers to take into account the contextual factors that drive livelihood precarity and thus to target more strategically anti-poverty programmes or activities to maximise their effect rather than equally distributing them across all places. For examples, interventions should focus on strengthening human and physical capitals in well-connected communities to ensure that households are able to diversify their livelihoods to off-farm strategies, while they should be targeted on providing financial capital and complementary livelihood opportunities during lean season in remote areas.

Although research articles are a platform for discourse and debate around their contents, it is often the case that the outcomes, as meaningful as they can be, miss the ability to influence conclusions and recommendations because of the lack of information on the behind-the-scene activities that have led to the final outputs (Brunsdon, 2015). Following the advice of Barnes (2010) and Stodden and Miguez (2014), this research was designed to be as reproducible as possible in order to be exploitable by governments and the civil society who would like to reuse the methods developed here. In spite of its reproducibility, this research mainly used open data for both environmental and livelihood monitoring and the codes used for data processing were made available to the local government in Odisha and to the FAO (Appendix D). Remote sensing products used in the research were chosen according to the following characteristics: available online and freely accessible to everyone with an internet connection. Moreover, their archives are also available online, which makes computation reproducible on the long-term. The data used for socio-economical analysis came from national censuses. Although such a dataset is not universal amongst countries, the type of information collected for censuses is similar, which makes this research widely repeatable, by way of adapting the indicators used (Rindfuss and Stern, 1998; Fox et al., 2003). Moreover, national censuses are part of public data that is supposed to be open and accessible to everyone; that is to say, available to all for free. Last but not least, this research mainly used free and open-source softwares for its processing in order to facilitate its reproducibility, such as R and QGIS.

7.2.3 Policy relevance

The findings from this thesis suggest several courses of action for public policies and schemes in India to reduce rural outmigration and, thus, to reduce urban and rural poverty. The National Rural Livelihood Mission (NRLM) that aims at enabling the poorest households to access self-employment and skilled wage employment opportunities seems to be well targeted to help

reduce livelihood precarity. This thesis supports the scheme's main focus of strengthening human (skill building), financial (access to credit) and physical (access to markets) capitals for the poorest households, through their participation in strong and sustainable grassroots institutions (Self-Help Groups). However, important changes would need to be made to ensure that it plays a role in long-term poverty alleviation.

This thesis argues that the NRLM should include community typologies in its approach to provide place-specific activities to strengthen livelihoods of the rural poor. In communities located near the main trading centres and well-connected, such activities should focus on human capital (skills) to ensure that households are able to adapt their livelihoods to off-farm strategies. In communities located near industrial areas, schemes focusing on strengthening household physical capital, especially through the ownership of private means of transportation, would enable households to diversify their livelihood opportunities. In remote agricultural communities, in addition to activities strengthening human and financial capitals, the NRLM should work hand in hand with the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) to ensure work stability throughout the year, especially during most critical periods for employment and when households face several expenses, which force them to go into debt or into distress migration. A specific emphasis of the scheme on providing stable employment during the lean season would reduce those risks. Moreover, it was shown that lack of access to financial services are a limit to the collection of MGNREGA wages as poorer households do not have access to bank services (Imai et al., 2010). Considering the great implementation of Self-Help Groups in rural communities across all India (Datta, 2015), the scheme should rely on them to provide financial services and money transfer to the most vulnerable households.

Overall, agricultural tenancy laws should be implemented and enforced to regulate rents and offer security of tenure to tenants, as this thesis demonstrated that smallholders' land dispossession by larger farmers drive these households into precarious livelihoods. Interventions in property rights would prevent land grabbing by agro-industries and large farm-holders (Ambagudia, 2010; Sahu and Dash, 2011), which would increase smallholders' bargaining power and secure their productive assets (Banerjee et al., 2002), thus reducing their likelihood to engage in precarious livelihoods and fall into chronic poverty.

7.3 Research limitations

Specific limitations associated with the data and methods used in this research have been discussed throughout the thesis to ensure that the interpretation of the research findings considered these key limiting factors. The following section reflects on the overall approach of the research, which consisted in quantifying livelihood capitals, activities and their relationships based on rapid rural appraisals.

The approach of this thesis was to scale-up to a larger spatial extent the knowledge co-created with the participants of rapid rural appraisals in order to characterise how drivers of precarious livelihoods vary locally, due to their access to community capitals. The study used proxies to

characterise livelihood capitals to quantify the diversity of factors identified by participants in order to characterise how they are associated with precarious livelihoods. However, indicators of livelihood capitals have been criticised, as they simplify the complexity of households' assets and capabilities to an aggregated number, which may lead to fallacious conclusions. The manual binning of variables under certain capitals is subject to interpretation, and its relevance and reproducibility might be questionable. Moreover, access to livelihood capitals is controlled by overarching systems of power (defined by class, caste and gender), which have been shown to be one of the main causal determinants of poverty in India. Therefore, this research avoided inferring any definite causal relationships throughout because of uncertainties surrounding the associations between livelihood capitals and precarious livelihoods. The links between context, livelihood capitals and precarious livelihoods are complex and the list of potential interactions and mediating factors is vast and often unquantifiable, as identified during the rapid rural appraisals and in the literature review. Dynamics and trade-offs between assets in the long-term have not been considered within the quantitative scope of this study, nor has been the questions of governance. The influence of power relationships on households' access to livelihood capitals have been broadly discussed in the different chapters, but its impact on precarious livelihoods has not been thoroughly investigated.

It was not in the scope of this research to give an in-depth understanding of the role of such factors. Instead this research focused on exploring how geographical datasets could be used in combination with participatory knowledge to characterise existing associations, acknowledging and accounting for the fact that they are context- and place-dependent. In spite of its limitations, this research certainly adds to the understanding of rural livelihoods by providing a tool that can enable researchers and practitioners to select archetypes of communities in order to conduct place-based analyses of livelihood systems.

7.4 Future work

This thesis showed that location and access to community resources have a significant effect on livelihoods, but there is room for further progress in determining new types of capitals that would encompass better the determining factors of livelihoods at the community level. Moreover, this thesis examined the effects of capitals on precarious livelihoods as a single snapshot and was not designed to evaluate the co-evolution of capitals and the role of different combinations of capitals on livelihoods in the long-term, including how household capitals interact with community capitals to create synergies or trade-offs. Although this research adds to the understanding of the question of scale regarding rural livelihoods, the relationships between community development and livelihood dynamics are not yet sufficiently accounted for in rural development studies. Dynamics of household capitals have been studied extensively but there is a lack of research on the dynamics of community capitals and their impact on households. Only few studies and frameworks have looked at the role of investment in community capitals on precarious labour, though its role on livelihoods and wellbeing is certain (Emery and Flora, 2006; Winkler et al., 2016). Figure 7.2 shows that investments in community capitals might

strengthen households' capacities and capabilities and create livelihood opportunities.

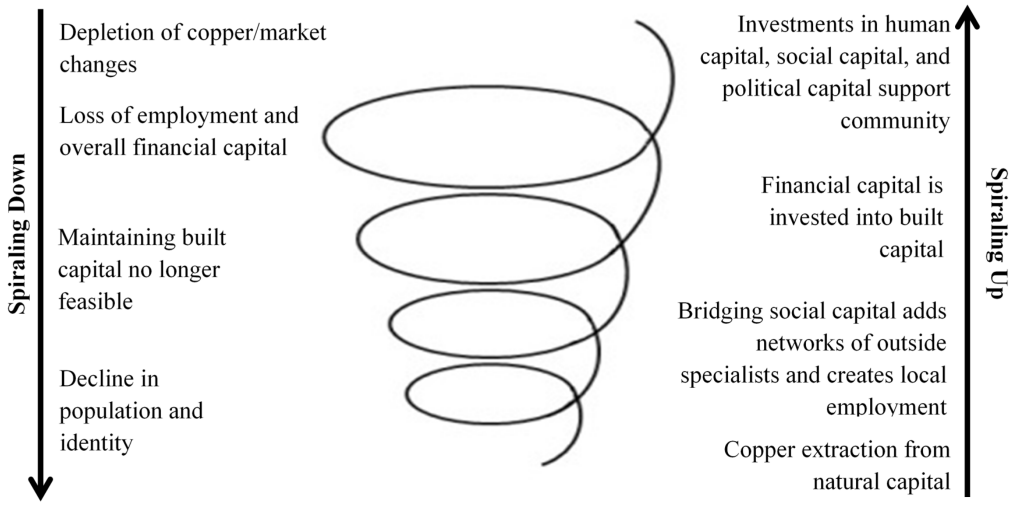


Figure 7.2: Upward spiral: increasing prosperity through investing in community capitals. This figure demonstrates the process of "spiraling up" or "spiraling down", conception of how investment or disinvestment in community capitals can impact community sustainability and livelihoods. This figure is from Winkler et al. (2016).

On the contrary, a lack of regulation or management of community resources might lead to a decrease of livelihood opportunities and thus to either migration or an increase in livelihood precarity. Such associations need to be looked further into, especially in countries where infrastructure development is uncritically seen as the fastest and simplest way to reducing poverty. Moreover, it appears necessary to also understand the mediating effect of power relationships of class and caste on how households might be benefiting from community resources. Overall, cross-scale studies looking at the dynamics of rural livelihoods in relation to community development could act as a bridge between policy programmes (often targeted at the community level) and the expected outcomes (often targeted at the household level).

7.5 Overall conclusion

This thesis addresses precarious livelihoods as a phenomenon that characterises rural household survival strategies, which is a serious long-term issue for policies concerned with reducing rural poverty in developing countries. Engaging in precarious livelihood activities, such as daily-wage agricultural labour, is a characteristic of rural survival, reflecting the continuing vulnerability of rural livelihoods. The increase of the proportion of households engaging in precarious activities in India is not only due to a readjustment of the economy from agrarian to industrial but rather is a persistent phenomenon that reflects the increasing inequalities in rural areas. Building upon the extensive literature that has shown the role of systems of power in perpetuating poverty, this thesis argues that location and access to common-pool resources also condition livelihood opportunities and might mediate or enhance the determinants of precarious livelihoods, defined as daily-wage agricultural labour and unemployment. The thesis

identifies, tests and then discusses three main determinants of precarious livelihoods: (i) location, through households' access to common-pool resources, defined as community capitals; (ii) households' access to private assets, defined as household capitals; and (iii) coping behaviours. These determinants are mediated through social status, relations and institutions, including caste, gender relations and kinship networks, but also the wider socio-political context and changes in the larger economy. Although such mediating factors are overarching determinants of access to wealth, this thesis showed that there are also significant household and community determinants of precarious livelihoods that could enrich our understanding of the drivers of rural poverty in India. Figure 7.3 presents a conclusion of the thesis by showing the place-based determinants of precarious livelihoods.

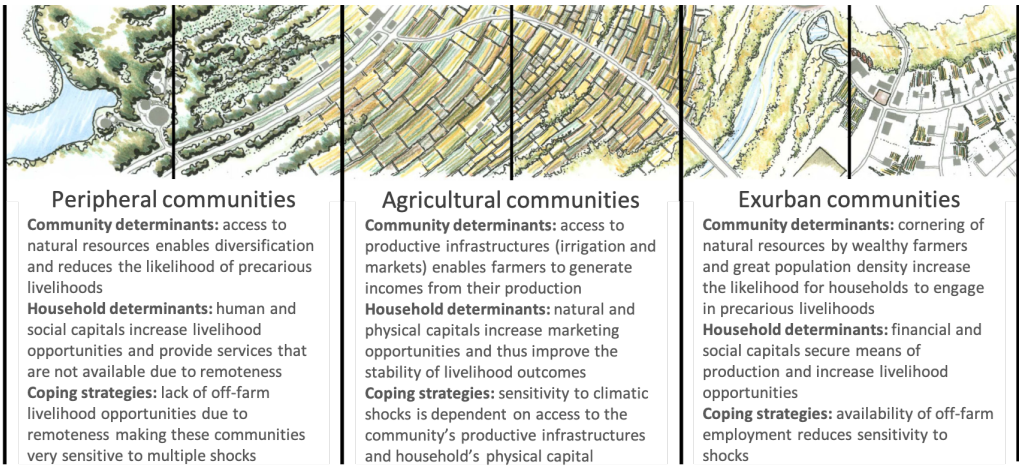


Figure 7.3: Determinants of precarious livelihoods. This figure synthesises the findings from this thesis and presents the key determinants of livelihoods depending on location. The transect illustration was extracted from the Kigali Conceptual Master Plan (AECOM, 2010).

Access to communal natural resources (associated with remote areas) enables households to diversify their sources of income, thus reducing the likelihood for their members to engage in precarious agricultural livelihoods. In these communities, kinship relations and labour force are determinant factors to reduce livelihood precariousness. They provide households with a package of safety nets that reduce their sensitivity to multiple shocks, which are a key driver of livelihood precariousness in remote locations. In rural communities, natural and physical capitals enable households to stabilise their livelihoods by increasing its outcomes through increased agricultural production and access to marketing outlets. The significance of these determinants and the sensitivity of households to climatic stresses are conditioned by the community's access to productive infrastructures, especially the availability of irrigation canals and their proximity to markets. Households located in exurban communities (associated with trading centres) are overall more likely to engage in precarious livelihood activities, notably because of the cornering of natural resources by few wealthier farmers and the necessity of financial and social capital to access alternative livelihood opportunities. As a conclusion, by providing a geographical perspective of the determinants of precarious livelihoods this thesis advocates for an integration of livelihood studies, community development approaches and landscape planning to address the pervasive issue of non-inclusive rural development.

APPENDIX A Fieldwork guides

Semi-structured interviews (state level)

To bring: map templates, business card, usb, participant information, consent form, recorder

Interview code: [yearmonthday]_[nameorganisation]_ki

INTRODUCTION	⊙ Participant information, consent form ⊙ **Presentation of the research:** aim and objectives, conceptual framework ⊙ **Organisation:** history, structure, mission, area of intervention and activities
BASELINE	*Main ways people make a living in the area. Probe for differences using relevant categories e.g.: farming, trading, fishing, natural resource exploitation, wage earners, remittances, migrant labour.* ⊙ **Hazard profiling:** map of natural hazards, timeline of main events ⊙ **Livelihood profiling:** map of the main livelihoods types ⊙ **Impact on the local economy:** shops, farms, fisheries, livestock, roads, markets ⊙ **Affected groups and impact chain:** links between hazards and livelihoods - which groups have been most affected and where are they? - why have they been most affected? why the others have not? - are the most affected groups the poorest?
COPING STRATEGIES	*Investigating people's strategies to cope.* ⊙ **Migration:** number of people who have left and who are likely to leave ⊙ **Activities:** likelihood of over-exploiting natural resources (cutting down trees) ⊙ **Assets:** likelihood of selling assets; which asset to be sold first ⊙ **Food security:** likelihood of reducing food intakes ⊙ **Recurrence:** impact of repeated climate hazards
LIVELIHOOD PROTECTION	*Details of the activities to put in place for reducing vulnerability.* ⊙ **Assessment:** priorities to preserve and support people's livelihoods ⊙ **Expectations:** role of governmental & non-governmental agencies ⊙ **Requirements:** changes for long-term development & vulnerability reduction
CONCLUSION	*Discussing fieldwork sampling, research outputs and potential collaboration with the organisation. Asking guidance for sampling strategy, contacts and datasets.* ⊙ **Research:** sampling strategy and expected outputs ⊙ **Collaboration:** data exchange, research dissemination, policy briefs, journal papers ⊙ **Concluding remarks:** contacts, consent check and acknowledgment

Rapid rural appraisal (community level)

To bring: canvas, felt pens, participant information, consent form, recorder, tea & biscuits

Interview code: [yearmonthday]_[villagename]_pra

INTRODUCTION	⊙ Participant information, consent form ⊙ **Presentation of the activity:** aim and objectives, outputs ⊙ **Village:** history, number of households, SCs & STs, literacy
VILLAGE MAPPING	*Co-construction of a village map with amenities and hazards.* ⊙ **Amenities:** educational, medical, drinking, communication, banking, recreational, approach, power supply, natural resources, markets ⊙ **Agriculture:** irrigated lands, land ownership, crops grown and livestock ⊙ **Hazards:** hazards-prone areas (agriculture, road networks)
BASELINE	*Main ways in which people in the community normally make a living.* ⊙ **Livelihood activities:** ranking of the most important activities - *e.g. rice farming, fishing, livestock, trading, agro-processing, transport, remittances, migration labour.* - for an "average" household and a "poor" household - differences between men and women ⊙ **Livelihood capitals:** "average" & "poor", asset control (men or women) - natural: access, to farmland, freshwater, forest - social: belonging to organisations, support from the extended family - physical: type of house, vehicles, equipment, livestock, seeds - human: labour power, knowledge, education, skills - financial: savings, number of livestock, income sources, access to credit
NATURAL HAZARDS	*Identifying the occurrence of natural hazards and examining changes in livelihoods.* ⊙ **Timeline:** type of natural hazard, area affected, damages on village amenities ⊙ **Livelihood capitals:** assets affected by climate hazards for an "average" household ⊙ **Coping mechanisms:** summary using an impact chain approach - capitals: coping with these impacts on assets and likelihood to cope; credit - activities: new/adapted activities undertaken to cope ⊙ **Differential effect:** between classes ("poorer"), between gender (men & women) ⊙ **Recurrence:** impact of repeated climate hazards
CONCLUSION	*Discussing needs and responses. Asking guidance for household sampling.* ⊙ **Needs & responses:** short-term and long-term actions to protect livelihoods ⊙ **Suggestions:** preparation for future natural hazards, how to reduce vulnerability *e.g.livelihood diversification/alternatives: horticulture, agro-processing, migration* ⊙ **Household identification:** photovoice, semi-structured interviews ⊙ **Concluding remarks:** other activities, consent check and acknowledgment

Participatory photography (community level)

To bring: cameras, printer, historic photo, consent form, recorder, tea & biscuits

Interview code: [yearmonthday]_[villagename]_pv

INTRODUCTION	*Introduce the photovoice methodology and facilitate a group discussion.* ⊙ **Presentation:** aim (influencing policymakers) and objectives, outputs, acknowledgment (printing pictures) ⊙ Participant information, consent form ⊙ **Ethics:** acceptable ways to approach someone to take his/her picture ⊙ **Theme:** brainstorming about themes to focus on and ways to portray it - natural hazards and livelihoods - asset mapping: resources and strengths - livelihood capitals
PHOTO 101	*Distribute cameras to participants and review how to use them.* ⊙ **Camera:** body, lens, sensor, flash card, battery ⊙ **Light:** "painting with light" - capturing the right amount of light on sensor - sun behind you *vs.* sun behind the subject to create silhouettes ⊙ **Composition:** - simplify the scene - fill the frame - aspect ratio - avoid the middle - leading lines - use diagonals - space to move - backgrounds - creative with colours - make your choice for a reason
DISCUSSION	*Selecting photographs, contextualising, storytelling, codifying issues, themes.* ⊙ **Selection:** choosing most significant photos that reflects the community's needs and assets (2-3 photographs per participant) ⊙ **Contextualisation:** meaning of photos, framing stories about photos, captions - what do they see here and what is really happening - how does this relate to their livelihoods - why does this situation exist and what can they do about it ⊙ **Codification:** issues, themes or theories that arise from photographs
CONCLUSION	*Discussing outputs.* ⊙ **Experience:** participants to discuss their photovoice experience ⊙ **Suggestions:** outputs, choosing pictures to print, influencing policymakers ⊙ **Concluding remarks:** other activities, consent check and acknowledgment

APPENDIX B Semi-structured interviews transcripts

B.1 Orissa University of Agriculture and Technology

B.1.1 Agricultural Meteorology Department

Research focus. Developed an agro-meteorological atlas of Odisha (2016). Climate risk management for agriculture based on optimal rain water-use at watershed level in Odisha (to be approved): pilot scale forecast for farmers to better manage risk

Agro-meteorology of Odisha. There is a decrease of rainfall in the coastal districts, decrease of solar duration, an increase of the number of heavy rainfall events. There are droughts and floods in the same areas.

Agricultural evolution. Before, farmers were using local varieties that were resistant to flood. But now, they use new varieties that are not tolerant to flood. For example, during the 2011 floods in Jagatsinghpur, local seeds resisted while new seeds rotted. Changing from local varieties to new varieties was a gradual process initiated in the 70s - 80s in order to increase the yield during a normal year. The most productive varieties were introduced in the 80s. Between 1995 and 2005, the government implemented a new policy that consisted in subsiding seeds that were of a variety older than 10 years. New seeds were more sensitive to fertilisers than the local varieties, allowing farmers to increase their yield (if using fertilisers). However, small farmers use very little fertilisers and there is a very high demand of fertilisers during transplant. Hence the government put in place a policy to develop storage and availability. To increase supply and so the availability of fertilisers, the government put in place a policy that allows everyone to deal fertilisers (fertiliser reseller) and activated the tracking of fertilisers for better

transparency. As a consequence, the quantity of fertilisers used by farmers has considerably increased: from 48kg/acre (2010) to 63kg/acre (2015).

Minimum Support Price. There is an imbalance between agriculture that starts to be well-developed and farmers who are not benefiting from it. This is partly due to the price policy and the *Minimum Support Price (MSP)*. The government keeps the MSP to a very low price, but it needs to be multiplied by two: even with a productive farm, it is too low.

Public Distribution System. Another problem comes from the Public Distribution System where poorest households are given rice that mainly comes from Uttar Pradesh. The rice is given to the poorest farmers who then sell it to the market as a *distress sale*. However, they don't get a high price for it because of the Minimum Support Price policy.

Agricultural Marketing. Now, people buy rice from supermarkets and no longer from local markets. Supermarkets need large-scale supply with a uniform quality and variety. Farmers need to sell the same variety and to bring the rice in big quantities in order to increase their bargaining power and sell to supermarket. Small-scale farmers need to associate together and uniformise the type of rice they grow, and then sell together to supermarkets. However, at the moment the government pushes for different varieties to be grown which is a problem.

Perspectives. There is a need for the reorientation of governmental policies: (i) increase of the minimum support price for farmers; (ii) decrease of the costs of production for farmers (subsidies for fertilisers, seeds); and (iii) investment in irrigation and uniformisation of seed varieties (subsidies). There are floods and calamities in Odisha, but it is possible to overcome that. Odisha is one of the poorest State, however it is not poor in nature. "It is a human-mind problem, because the nature is there". One of the key point for the future and for agricultural development will be micro-irrigation.

B.1.2 Department of Plant Breeding and Genetics

Land types. Upland and midland (Khorda, Nayagarh): does not retain water; prone to drought; need of varieties with deep roots (can extract water)
Lowland (Baleswar, Jagatsinghpur, Kendrapara): major problem in coastal areas; prone to flash flood (plant completely submerged); prone to water logging (50 cm water depth); need to have varieties that are resistant to both submergence and stagnant water
Salinity is not a big problem during Monsoon season, it is a problem only during *rabi*. Need to develop *rabi* paddy tolerant to salinity.

Paddy varieties. The vegetative stage is the most vulnerable stage. Farmers still grow traditional varieties with a deep rooted system that can extract water (cultivated in upland). New varieties developed by IRRI: can manage up to 10-15 days of water scarcity. Total of rice varieties: 69 *Swarna Salowan* variety is now gaining success amongst farmers (developed from local Orissa variety). Maturing rice: 90 days (harvest at the end of Monsoon around September 15) 4000 Rs net profit for 1 acre of land (1998): recommendation of sparing some land for aromatic rice to increase incomes.

B.2 Utkal University

B.2.1 Department of Geography

Kendrapara. Migrants from Bangladesh and West Bengal cut the mangrove for prawn cultivation that increases salinity. Livelihoods based on forests (wood, coal) and shrimp farming. Traditional technique for shrimp farms: during rainy season, farmers build a dam to keep the water for the next 4-5 months and then use this water for shrimp farming.

Agriculture. Farmers from Andhra Pradesh come to Odisha to farm the land, they pay a small wage to land owners and then cultivate the land. Farmers don't want to change their practices, the government put incentives for new varieties but farmers are too traditional and don't use them. Farmers disengage from agriculture because it is seen as a 'bad job' and they want to have access to facilities and services so they move to urban centres (hence urbanisation problem). Lack of mechanisation compared to other states.

Urbanisation. Problem of water drainage: traditional way was fine but urbanisation and construction of highways stop the natural process and creates flood prone areas. Fast urbanisation, cutting trees.

Coping strategies after disasters. Farmers lose their crops because of floods/droughts. Compensation from government is not enough. They still have to sell their animals/assets/lands.

B.3 Nabakrushna Choudhury Centre for Development Studies

We have a project about revitalising agriculture in India. We work as a consortium with academics and policymakers with the objective to deliver an executive summary to the State of Odisha and the Central Government of India. At the moment, we are in the pilot stage, running a comprehensive study. The main aim is to bring different capitals to a rainfed context and to bring different systems together through an integrated approach. In your seminar presentation,

you talked about a part of your research that is looking at the detection of climatic and agricultural stresses. It could be a real added-value to our project because we have the objective of locating the stressed rainfed areas in order to reintroduce millet instead of paddy, that is highly sensitive to drought. The overall aim of the project will be to secure on-farm livelihoods for those communities.

B.4 Department of Agriculture

B.4.1 Minor irrigation and water-use training institute

Climate Change and Disaster Risk Reduction in Agriculture. Refreshers' training for extension functionaries (Gr - 'B'). Adaptation to climate change: (i) training; (ii) index-based crop insurance; (iii) early warning systems; and (iv) integrated farming systems. Decrease GHG emissions: (i) crop rotations and integrated crop management (CO_2); (ii) integrated trees and livestock with crops (CO_2); (iii) drip irrigation (CO_2); (iv) aerobic rice instead of anaerobic (methane); (v) directly seeded rice (methane); (vi) brown manuring: co-culturing of *sesbavia* with rice for 25-30 days then knocking down with ether; and (vii) smart nitrogen management.

B.5 Odisha Disaster Management Authority

State of disasters in Odisha. Since the last 20 years, there has been a lot of climate logical disasters such as droughts, cyclones and floods: flood (2011), drought (2015), cyclone (2013, 2014). Every year, there are climate logical disasters in Odisha. They first affect agriculture and thus livelihoods. Agricultural farmers depend on agriculture for their livelihood, so they are very vulnerable to climate disasters. It is one of the main cause of migration in coastal districts.
Causal link: flood/drought $\rightsquigarrow$ agriculture $\rightsquigarrow$ livelihood/local economy $\rightsquigarrow$ migration.

OSDMA activities. OSDMA started its activities after the 1999 super-cyclone during which about 10,000 people died and all telecommunication infrastructures were destroyed. OSDMA implements disaster-related activities in the whole State in order to mitigate the effects of disasters. A block is considered as affected if there is a crop loss of more than 50%. In such a case, everyone in the block will get a compensation. Crop loss is based on rainfall estimates and then checked with field experiments (if those fields have more than 50% loss, then the block is considered as "affected").

Immediate measures. *Basic needs:* (i) cyclone shelters: OSDMA builds them or identifies shelter buildings (schools, hospitals); (ii) drinking water: pre-disposed inside the shelters before a disaster; and (iii) food (dry fruits, rice, potatoes) pre-disposed inside the shelters before a disaster. *Assistance:* (i) disaster response workforce/army with machineries to clear roads; (ii)

pre-disposition of electric pylons nearby in order to rehabilitate the provision of electricity after a disaster; and (iii) medical facilities: doctors, nurses, medication. *Damage assessment and compensations:* (i) subsidies to start next crop (seeds, fertilisers); and (ii) compensation for house damage.

Long-term measures. Infrastructures: embankments, warning towers with speakers (200) for early warning in the case of tsunamis or cyclones (+ radio/tv). Field activities on how to prepare a disaster. Long-term loans for agriculture (2-3% interest/year, 5 years repayment).

Agricultural communities. *Agriculture:* the state of Odisha is mainly a rainfed area: people rely on monsoon, thus are really affected by natural disasters. The coastal areas is mainly irrigated with drainage facilities. Sometimes there are some other cultivations such as coconut, vegetables and pulses (winter)
Types of communities: (i) coastal villages (depend on fisheries); and (ii) rural villages (rice/flood-prone area).

Climate variability. Because of scarce rainfall, farmers have changed their agricultural practices. Actually, now, during monsoon there can be up to 5 days in a row without rain. Farmers now cultivate short-cycle rice, they changed the variety of crop they grow. There are floods and droughts everywhere, but if land is irrigated then there are less droughts.

Coping strategies. In the case of the loss of crops, households will sell their domestic animals, their assets and sometimes their land. There might be some people selling the subsidised rice (1Rs per kg) in the case of distress sale, but there is no official report of that. Different states supply Odisha in agricultural commodities (e.g. potatoes from West Bengal) but it is impossible to transport them during disasters. As a consequence the price for basic commodities increase during disasters. For example, 1 day before cyclone Phailin, the price of candles increased by 3-4 times.

Perspectives. OSDMA has increased and projects to increase the calamity assistance (e.g. increase in rice provision, school fees for free if disaster). Many initiatives led by the government, for example the scheme of seed subsidies in order to promote the use of different crop varieties.

B.6 Odisha State Agricultural Marketing Board

Aim. To regulate markets and give remunerated prices to farmers

Problem. Brokers/middlemen who buy from farmers and sell to traders

Marketing in Odisha. There are 66 regulated market committees in the different parts of Odisha. Only a group of licensed traders are involved in the bidding and allowed to bid. The bidding start price is based on the previous day median price (>50%). Then traders are bidding and farmers accept or refuse the offer. If a farmer says "no" then he keeps his production until the next day. *Crops traded:* vegetables, coconuts, paddy, maize, cotton, onion and ginger.

Infrastructures available in the market. Resting and recreational facilities for farmers; banking facilities; and information boards for previous day's prices (minimum, maximum, average)

Impact of climate variability on prices. There is an impact of floods/droughts on prices Prices depend on supply/demand so if supply is less then price is greater

For paddy, there is the MSP fixed by the government; nobody can sell under that price. The government has implemented a programme (APMC) that gives free mobile phones to farmers so they can get information on prices through texting information system.

B.7 Integrated Coastal Zone Management Programme

B.7.1 Department of Ecology

ICZMP. First integrated project in India. Advantages of project integration: brings different State departments together and saves money, avoid double work. Initial assessment: coastal problems with erosion, a huge diversity of ecosystems and great coastal length. Area of intervention are hotspots: Chilika lake and Mangroves. After the independence, people from Bangladesh and West Bengal came and cut off the mangrove trees. The mangrove was the host of many endemic species: reptiles, crabs and prawns who were coming in the mangrove to nest their eggs. As a consequence, the population of reptiles decreased, sea population of crabs and prawns decreased due to the reduction of habitat for their eggs.

Project activities. *Protection:* (i) ecological protection by the Forest & Environment Department (marine protection for turtles' nesting, protection of rivers/sea: interdiction to fish with motorboats, protection of mangroves: interdiction to cut off trees); (ii) livelihood protection by the OTDC/ARD (because of the prohibition to fish using motorboats, many people have lost their livelihoods; need to provide new livelihoods to dwellers, for examples fisheries, tourism: support to 60 villages); (iii) physical protection to disasters: shelters by OSDMA (started after the 1999 super-cyclone, maximum distance of 2.2km to a shelter, physical protection but no livelihood protection); and (iv) physical protection to disasters: embankments by IIT Madras –from 2007, several places with saline ingression and large-scale erosion, e.g. Pentha (Kendrapara district): about 400 m area of the coast under water now (starting in 2007 until now), limitations: embankments can lead to ecological destruction (habitat, egg nesting), trade-off

between people's protection and ecological protection (have to go for the least worst option)–.
Coastal development by COIR/Department of Culture/HUDD: (i) agricultural development: coconuts need saline environment and is a source of income; (ii) cultural development: state archeology (temples, British colonial ports); and (iii) urban development.

B.7.2 Department for Rural Development

Coastal zones. Coastal zones are vulnerable to natural disasters; they are the most affected zones. Livelihoods are very affected by natural disasters, especially BPL population. The main livelihood of people in coastal zones are fishing communities (profession) (90-95% of the population). In coastal zones, there are very few Scheduled Tribes. There are only Scheduled Castes, general castes and SEBC (Socio-economical Backward Castes). Fishermen sell fish to middlemen who sell to Paradip/Bhubaneswar. They sell at a very low price because they don't have any storage facilities so they can't store fish. In Kendrapara, people are mainly refugees from the end of the war (1971). They cultivate, do fishing and pisciculture but the lands belong to the government (villagers don't own it).

Community categorisation. *Traders/sellers:* own one or many troller boats (customised for long-time fishing 10-15 days, 10 men); hire poor people from local community as worker in boats; least affected by floods/cyclones because they are working in many different locations.
Community owned-trollers: some communities have 1 troller, usually dwellers of these communities have other wages so are less affected by natural hazards.
Contract labourers: men folks go for 10-12 days on traders-owned boat for fishing, women stay in village, traders provide food and daily subsistence to families while the man is away. When men come back, they get the rest of the money that they use for daily use.

Financial inclusion. *Governmental schemes:* the zero-balance account government scheme: allow to have a bank account even without balance; and micro-banking products.
Access to banking facilities: Access to banking facilities is a major issue. More than 70% of rural people in Odisha still don't have access to banking facilities. But if it is available, dwellers can have access to banking products. Now customers have the right to know all details concerning banking products and prices (mandated by central bank of India).

Livelihood alternatives. The government banned fishing during tortoise nesting time (4-6 months per year). As a result, fish catch has decreased in the State. However, communities don't have many options for alternative livelihoods (no land). ICZMP work on livelihood diversification (non-farm and non-fishing activities).

B.8 Omega Programme

Aim of the programme. To support the government of Odisha in introducing some reforms: financial, industrial and on livelihoods (by strengthening flagship schemes related to livelihoods).

Rural development schemes. *Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS):* (i) provide employment –> 100 days of work guaranteed every year at 174 Rs/day. Money transfer within 15 days but usually it takes about 2 months. Problem: people are sometimes far from banks and don't know when the money is credited => there is a need to inform them (through m-pesa system for example); and (ii) creation of assets –> productive assets, water harvesting, rural connectivity.
National Rural Livelihood Mission (NRLM): (i) ensure livelihoods (stabilisation and diversification); and (ii) support groups (SHG, farmers, youth).

Rural development issues. *Distress migration:* mainly in Western Odisha with the big festival in September (New Harvest) for which villagers want money. *Lean period (July to September):* no agricultural work, MGNREGS scheme cannot provide work during this period (rainy season), lack of income generating activities. As a consequence, villagers (usually landless) take loans (35,000 - 40,000 Rs // 70 - 80 % of the total amount) to money lenders who book them in migration labour (which will occur after the festival)

OMEGA activities to limit distress migration. Try to converge both MGNREGS and NRLM schemes, capacity building at the government level. Ensure 10-15 days of work during rainy season by developing new types of work possible: (i) land development through FRA; and (ii) plantation activities. Recommendations to the government: (i) increase number of working days to 150 days for MGNREGS - *accepted by the government for the districts of Balangir and Nuapada*; (ii) distribution of job insurance certificates to inform all villagers; (iii) encourage migrants to participate in groups by providing them with money support through NRLM (between 30,000 Rs and 50,000 Rs) and developing small income-generating activities (kitchen gardening, poultry); (iv) promoting climate-smart agriculture, discussion with Airtel and BSN to provide weather-information to farmers and creation of climate-resilient assets (irrigation, wells).

Impact and future work. Distress migration has been decreased drastically in the districts of Balangir and Nuapada (only 10% migration now). End of OMEGA project in 2016, new project under the umbrella of the Government of Odisha *"Infrastructure Climate Resilient Growth"*.

B.9 Odisha Tribal Empowerment and Livelihoods Programme

B.9.1 Livelihood department

Area of intervention. Southern Odisha, tribal population >75%, watershed of 500 ha with arable land for agriculture and non-arable land (hilly, forest, water bodies). Basic statement: natural resources (water, land, animals) are degraded.

Project aim. To regenerate natural resources through different interventions: (i) restoring resources (forest/water bodies) by encouraging dwellers to take up forest plantation, sustainability depends on water, which is scarce (e.g. 4 months of rain in the hills => plantation of mango trees/forest to retain water and keep it in the soil for a longer period); and (ii) capacity building/empowerment through facilitation.

Livelihoods. 70% agriculture (62% primary); with land => land-based activities such as farming/plantation; without land => animal husbandry, forest/timber products, bee-keeping. Main crops: paddy/cereals (30%), pulses (30%), vegetables (30%)

Food security intervention. Increase agricultural production levels through specific crops (in order to keep balance): C4 plants (maize) for carbon harvesting and root crops (tapioca, yam, sweet potatoes). Provide employment for non-land owners to increase their incomes so they can buy food.

End of project. After 7 years. Almost 99% of the villages have met the water requirements. Partnership between government and civil society, 90% of the funds go to the communities. All the work conducted by the communities, no outsiders. Challenges: need to be a bottom-up approach.

B.10 Regional Centre for Development Cooperation

RCDC Activities. Project finished end of January 2016.

Livelihood activities. How to improve livelihood status: (i) embankments around ponds so pisciculture not affected if flood; (ii) saline and flood resistant paddy –local and new varieties, very costly to put fertilisers (in the end, net income is similar to organic farming)–; (iii) drainage canal in water logged area that can be used as irrigation system for *rabi*; (iv) promotion of organic vegetables (better yield than traditional); (v) promotion of youth in agriculture: need to increase income; pisciculture production; (vi) rain-water harvesting structures in saline areas

(rooftop structure or specific pond for drinking water); (vii) clean stoves: environmental friendly (less smoke); less fuel consumption (50% instead of 100%); portable; (viii) importance of forest because provide resources (honey, leaves, *moha* flower for food and liquor): 60 items in total; and (ix) mangrove: block tidal waves and can be used as a nursery for landless people (work on community land).

Disaster preparedness. How to prepare communities to cyclones: (i) training on shelter management and water supply; (ii) training orientated for youth: linking points with government during disasters; and (iii) sustainability: work in collaboration with Gram Panchayat.

Livelihoods and climate variability. Natural hazards: Kendrapara with cyclones and some floods, Jagathsingpur: cyclones and water logging. Livelihoods: rice and pisciculture in coastal, millet elsewhere. Such mixed livelihoods increase productivity by 2. Governmental schemes: promoting business agriculture and commercial plantation. In Kendrapara, there are skilled plumbers (famous, very good incomes), considered as "good" migration by RCDC contrary to "distress" migration (seasonal).

APPENDIX C Reports from the rapid rural appraisals

C.1 Jagulaipadar

Block: Kanas
Village: Jagulai Padar
Hamlet: Mallisahi, 75 households
Focus group: 14 men, 10 women

C.1.1 Resource mapping

C.1.2 For women

Water: river, 5 tube-wells (4 functioning but only 1 good for drinking, 1 not functioning), pond.
Livestock: cow (for milk, cow dung for fuel and fertilisation), goats (for mutton), hens, ducks (for food).
Sewing machine (2-3 women have, but they want one for SHG group).
Electricity for *coire* processing (1 SHG). Raw material with which they produce mats and ropes. The government gave training in 2013 but no machines. Need to go 40 km to get the raw material.
School: in hamlet for class 1-8, no higher secondary school
SHG: 6 SHG groups in the hamlet, they want to develop income-generating activities. Women are purely dependent on men at the moment. Need skill-training and support. Want each woman from the SHG to earn something for their house and for their children. They do *tontine* system for household purposes and for boat/fishing purposes.
Road: need concrete road because it gets destroyed during rainy season.
Bank: give a loan after you go to the bank many times; difficult to get a credit.

Issues. Grass in the river. Severe problems of drinking water (health issues). Lack of latrines. Unemployment for women/youth/some men is a real problem, even if little educated.

C.1.3 For men

Resources. Fishing in river (but now less than before, so they migrate to Chennai/Kerala).
Farming (paddy): no *kharif* cultivation because it suffers from heavy flooding (*"I've never seen kharif cultivation"*). Only *rabi* cultivation.
Water: river, pond, tube-well
Livestock: cow, goat, hen
SHG groups (only women)
Primary school: there is one project primary school (extended from the main school in the village)
Communication: mud road and narrow concrete road
Daily wage: from farming, construction and road work
Village market: for vegetables
Temples (3)
Water irrigation: 3 irrigation structures, water panchayat governmental scheme, pay water tax and electricity, managed by block office, collective resource with committee.
Wood boats without machine (65)

Issues. Drinking water, no connecting pipe system with irrigation, grass in river $\rightsquigarrow$ difficult for fishing, no veterinary dispensary, no playground, no restroom in temple, need of community shelter (closest shelter is 5 km at the moment).



Figure C.1: Resource map for Jagulaipadar. By women (left) and men (right).

C.1.4 Caste issue

Scheduled caste is the main population in the hamlet, 12 households are general caste (minority now). SC are the majority and they have a strong voice so they have the power. General caste do not benefit from governmental schemes and subsidy loans for SHG => SC women asked general

caste women to leave SHG groups. There are no more mixed SHG groups now. *"Whatever is left, we get that"* General caste livelihood/incomes: agriculture (were the first one to get access to irrigation and then they shared with SC) and temple. *"We keep silence to keep no tension. If we want to raise tension, then there will be tension."*

C.1.5 Livelihood categorisation and wealth ranking

Total number of households: 75

Table C.1: Wealth ranking for Jagulaipadar.

Category	Characteristics
Medium 10 households	- own 1 boat - own land: 1 acre - own cattle: 1 cow - paddy harvest for 8 months - *asbestos* house (under *indra havas* scheme) - issue: disaster like flood/cyclone affect their livelihoods
Poor 45 households	- 1 boat - no land and no livestock - paddy for 8 months - *kutcha* house - share-croppers (rent land from landlord) - migration July to January (Gujarat, Kerala, Chennai)
Very poor 15 households	- daily wage labour, sometimes dry-fishing from Chilika - no permanent job and no land - very old *kutcha* house - do not own livestock

C.1.6 Impact chain of natural hazards

Chilika lake is drying and there is an accumulation of waste materials that blocks the entrance. People stopped fishing and doing dry-fishing activities for the last 10 years. They now migrate to Kerala and do sea-fishing (but it is very dangerous). Sometimes after a disaster or if it is difficult to manage the house (crisis period, disease of parents), they have to sell their land. Sometimes there is uncertain rain and they lose their *rabi* crop: water scarcity (1994), insect attacks, too heavy rain and hailstorm (2012). Floods affect the whole village and are increasing. When there is flood, we stay in shelters or on the boats.

C.1.7 Other information

Marriage: man goes to woman. If parents accept the wedding then the girl's family has to pay money to the boy's family. After marriage, the bride moves to the groom's family and takes her husband's caste and sub-caste.

Heritage: if son, the parents give land. If daughter, parents usually have to sell land to pay for the marriage.

C.1.8 Photovoice



Figure C.2: Water. [Women] Women collecting water from the river. The river is full of grass. This grass spread everywhere for the last 7-8 years and it is expanding. It is mainly there from December until June (left). We have tube-wells but minerals are there, it is salty. We can't use them for drinking purposes, we only have one tube-well for drinking water (right).



Figure C.3: Self-Help Groups. [Women] Sewing machine, an income-generating activity for women (left). SHG group photo (right).



Figure C.4: Fishing. [Women] Fishing boats, an income-generating activity for men (left). Fish storage box made from a pharmaceutical box (right).



Figure C.5: Sanitation. [Women] There are no latrines in the village. People have to go for open-defecation.



Figure C.6: Crop cultivation. [Women] Rabi crop with pipes for irrigation (left). Seed bank for paddy storage. We can store paddy for up to 1 year with this structure (right).



Figure C.7: SHG *coire* activities. [Women] Coire processing to produce mats is one of the main activity of our SHG group. The machine was given by the government and we received some training as well.



Figure C.8: *Coire* products. [Women] Ropes and raw materials for coire processing (left). Finished mat. We sell to a company for 50 Rs, they come here. If we would sell them ourselves, we would get 60 to 70 Rs (right).



Figure C.9: School and latrine facilities. [Men]



Figure C.10: Water. [Men] We have tube-wells but we can't use most of them because they have salty water and are full of iron (left). Bathing pond (right).



Figure C.11: Fishing. [Men] We used to fish a lot in the river but now because of the grass it is very difficult.



Figure C.12: Irrigation. [Men] We have an irrigation motor-pump (left) to irrigate our rabi cultivation (right).

C.2 Gurubai

C.2.1 Resource mapping

Village: 245 households
Focus group: 17 men, 8 women
Landscape: flat land, very few trees
Buffer of 10 km around Chilika for fishing-dependant livelihoods.
Rainfed area, no irrigation. All dwellers are from general caste. There are some fishermen caste around but they are not in the village. 85% of villagers rely on fishing but they are not from "fisherman" caste.

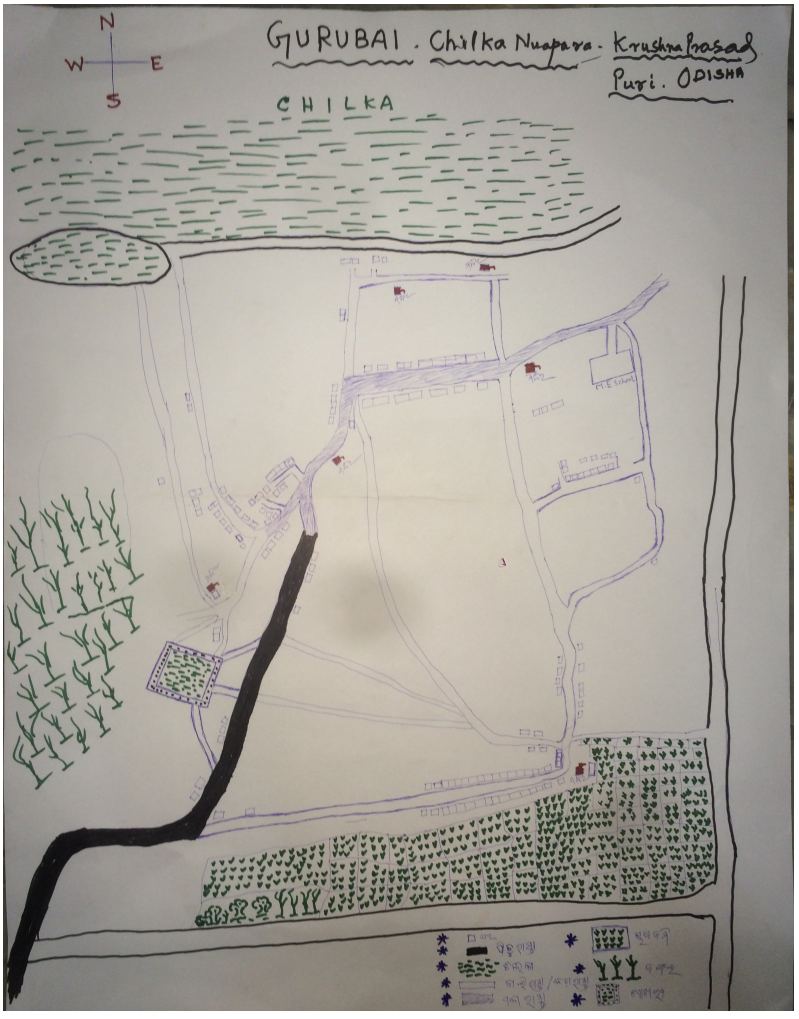


Figure C.13: Resource map for Gurubai.

C.2.1.1 For women

Water: pond, well, Chilika.
SHG: 6 groups, each group around 10-15 members. Government promised loans but didn't do

anything. SHG for the last 20 years but still don't have access to credits from the government. Activities: collecting money, savings, give loans to members with interests. Banks (Gramobank, 2 km) are not giving loans to SHG
Domestic animals: cows, buffalos, goats, poultry, sheeps.
Hospital facilities: 3 km distance or 60 km for major cases
Women don't do any agricultural activities nor fishing in Chilika. They got a training from ORMAS about "incense sticks" making but it's a very tiring and time-consuming activity (1Rs/kg)

Issues. Problem of access to credit for SHG: there are around 30 SHG in the block but block officials are selecting 2-3 groups for scheme so there is a lack of access to schemes for many SHG. They would use loans to generate income: buildings for livestock-based farming (cow, goat, poultry). Women and Child Development (WCD) has not reached here, lack of communication facilities (road): "that's why we are not accessing any governmental scheme". Very far from market and from district HQ (Puri, 60 km), they have to go to Puri to ask for government schemes. Latrines: only 2-3 households have good houses with latrines; rest do open-defecation.

C.2.1.2 For men

Water: well, pond, tube-well, Chilika.
Forest: acacia tree for crop protection against cyclones.
Land: agriculture (30%), salt land (60%), lay land (10%). *Rabi:* groundnuts, green gramdal. *Kharif:* paddy.
Housing: *kutcha* house (80%); asbestos (15%); *pucca* house (5%).
Cyclone shelter: 3 rooms, capacity 2000 people.
Youth clubs (3): village development, voluntary work.
Education: upper primary & 2 pre-primary.
Domestic animals: buffalos, cow, goats, poultry (ducks, hens).
Communication facilities: concrete roads, sand roads.
Government block: *panchayat* office, forest office (3 km distance)

Issues. Priority is water irrigation: water scarcity for agriculture (during *rabi* cultivation), droughts for last 3 years during *kharif*: completely lost their crops. Only one pond but quite old because of the lack of renovation; problems of bathing. Chilika is drying which affects cultivation of fish and prawns. Deeply affected by cyclones because very close to the shoreline; they need *pucca* houses. Road communication is poor; sand road difficult to use during monsoon.

C.2.2 Livelihood categorisation and wealth ranking

Total number of households: 245

Wage labour: mixed (road construction, fishing, agriculture).
Boats: 40 in the village, people share the boat with their relatives and the rest go directly in the water to fish.

Table C.2: Wealth ranking for Gurubai.

Category	Characteristics
Better-off 20 households	- government employment - businessmen - own vehicles - have savings (bank balance) - house made of bricks (*pucca* house) - own agricultural land (1 acre) - own cattle: 2-3 cows, buffalos
Medium 100 households	- own little agricultural land (0.5 acres) - own cattle: 1-2 cows - no government employment - go for 6 months migration - medium housing (*asbestos* house) - go fishing (if not, they would go for 12 months migration) - owns fishing boat (40 households) - own cattle: 1-2 cows
Poor 90 households	- no employment - no land - no business - *kutcha* house - wage labour all year - fishing - no livestock
Very poor 35 households	- no job - no land - wage labour 12 months - begging - very old *kutcha* house - do not own livestock

Migration: Migration to Bangalore, Chennai, Kerala for construction labour. Remittances for daily household maintenance and repaying loans; no savings.

C.2.3 Seasonal calendar

Seasonal migration: Not constant, whenever they find food scarcity or drought they go for migration.
Goat selling: All time according to their need/demand.
Main expenditures: From July to October: festival and wedding times.
Credit: the rich go to the bank (2% interest), the medium/low don't have access to bank credit so go to landlords (5% interest).

Table C.3: Seasonal calendar for Gurubai.

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Monsoon						⊙	⊙	⊙	⊙			
Water scarcity				⊙	⊙							
Agricultural droughts								⊙	⊙			
Food scarcity								⊙	⊙			
Grazing scarcity				⊙	⊙							
Kharif cultivation	H	H				S	S	⊙	⊙	⊙	⊙	⊙
Incomes	⊙	⊙										
Expenditures							⊙	⊙	⊙	⊙		
Credits							⊙	⊙				

C.2.4 Timeline

Village creation: 300 years ago (by King), 12th generation now, used to be a forest area with wild animals
1985: road and electricity
2005: hybrid seeds from the government and fertilisers. Good harvest but not sufficient because now they face droughts. Seeds are flood resistant but it is useless as we face water scarcity. Seed 1009 Subarnamasuri Sarla Puja.

C.2.5 Impact chain of natural hazards

Natural hazards. Cyclones (2013) –> lost standing crops and houses no electricity for 6 months. Drought: for last 2 years (2014, 2015) –> *kharif*: completely lost their crops. Not officially declared as a drought-prone area by the Government because too close to Chilika

Livelihood dynamics. *Medium* $\rightsquigarrow$ *Poor:* when there is water scarcity and they lose their crops, medium households see their livelihood affected because they rely on agriculture and Chilika only; they don't get any wage. In this case, they take loans, sell animals, bond assets, go to do wage labour or sometimes sell land.
Poor $\rightsquigarrow$ *Medium:* if there are good incomes (good fish catch in Chilika, good agricultural harvest) or if they have good incomes from migration. They buy some land and get to higher socio-economic status; but very rare.
Inheritance: land is divided between sons but not with the daughter. Usually they sell land for the daughter's marriage. Fields are getting smaller and smaller.

Recovery time: between 1 year to around 2-3 years.

C.2.6 Photovoice



Figure C.14: Livelihood activities. [Men] Man from a poor household taking rest after begging in the village (left). Man and his stall of sweets and snacks (right). This activity does not provide much income (poor household).



Figure C.15: Livelihood activities. [Men] Unemployed youth playing cards. They are waiting for labour; if there is a requirement then they will go (left). Daily labourer doing construction work (right).



Figure C.16: Livelihood activities. [Men] Woman collecting wood for fuel/cooking and man going to fish in Chilika (left). Collecting small fish in ponds (right).



Figure C.17: Housing. [Men] Poor people house with a very bad roof.



Figure C.18: Water. [Men] Tube-well currently not functioning well because of water scarcity (left). Pond full of nalia grass, it is not possible to use it anymore (right).



Figure C.19: Fishing activities. [Men] Fishing nets maintenance for drying (left). Arranging fish nets in Chilika lake (right).



Figure C.20: Fishing activities. [Men] Fishing boat (left). Chilika prawns (right).



Figure C.21: Fishing stall. [<em] Stand to sell fish in the village. They buy from fishermen (100 Rs/kg) and then selling (110 Rs/kg).



Figure C.22: Mat and basket handcraft. [Men] Low income households make mat and baskets from leaves to generate some incomes.

C.3 Keutajanga

Village: Keutajanga
Gram panchayat: Sisua
Block: Astaranga
District: Puri
Villagers can't go fishing because they are not from the "fisherman caste", which is a lower caste.

C.3.1 Resource mapping

Water: 4 wells: 3 of them are functioning, 4 tube-wells (salt water, not good for human consumption), village is surrounded by sea (250 m) and 3 rivers, 3 ponds but grass in it.
Forest: village-people initiative, community forest (*cajurina*), protect from wind/cyclones/waves.
Agriculture: rainfed area no irrigation because groundwater is saline. Betel vines (40 HH): structure gets higher every year by adding soil, it becomes a good way to avoid flood and can be used as a shelter if high waves/tides. *Kharif* paddy and *rabi* pulses but not every year; this year the rain was delayed so land was still wet when harvesting *kharif* => land was suitable for *rabi*.
Land: individual agricultural land and community land: nothing on it at the moment, want to have a forest nursery there to plant a forest.
Cyclone shelter

Village development committee: community ponds for pisciculture, incomes are invested in community forest.
Electricity
School: (class 1 to 3) then have to go 5-6 km from village.
SHG groups: two SHG groups, saving and credit activities.



Figure C.23: Resource map for Keutajanga.

Issues. *Water:* problem of drinking water, no irrigation facilities, grass in pond, need rain harvesting structure.
Embankment protection: need another forest to protect embankment, need stone structure to protect embankment between sea and river.

C.3.2 Livelihood categorisation and wealth ranking

Total number of households: 45 Number of betel vine rows is a proxy of wealth. Income from betel vine all year but peak from October to December during harvest time.

C.3.3 Impact chain of natural hazards

Super cyclone 1999: took loans from bank and started migration just after cyclone. Frequent crop loss during *kharif* because of floods; as a consequence, men migrate to Gujarat/Mumbai for construction labour/daily wage. If there is a cyclone they will also lose betel vines (but not

Table C.4: Wealth ranking for Keutajanga.

Category	Characteristics
Better-off 5 households	- 1 acre of land - 6 months migration - 6 months food - livestock: 2-3 goats & 1-2 cows - 25-30 rows of betel vine - *asbestos* house (IAY governmental scheme)
Medium 10 households	- share-croppers for paddy - daily-wage labour - 25-30 rows of betel vine - 4 months of food & ration cards - *kutcha* house - livestock: 1 cow & 1-2 goats
Poor 12 households	- share-croppers for paddy - betel vine (15-20 rows) - *kutcha* house - daily-wage labour & go for migration
Very poor 18 households	- betel vine (10-12 rows) - daily-wage labour only - very old *kutcha* house - don't migrate

during flood) - it takes 6 months to recover. Agricultural productivity is decreasing since 1999 because of salinity.

Example of migration for a household with 5 members:
1-2 members engaged in agriculture, the rest go for migration all year except during *kharif*. If there is a crop loss => all male members go for migration. They use middlemen for migration work.

C.4 Machhagan

C.4.1 Resource mapping

Village: Machhagan
Block: Balikuda
Total households: 22 Total population: 110

C.4.1.1 For men

Agricultural land: other side of the road: *kharif* (paddy) and *rabi* (black gram) cultivation (don't go on migration). No vegetables. *Rabi* cultivation only, because of tidal flooding (in this case, people sell their *rabi* harvest to buy paddy and go on migration. Seeds: everyone use

high yield seeds (HYV) now, started 7 years ago, main variety used (60%): *Puja Tulasi Borsa 1018*."We're happy with those seeds. They are not flood resistant but they have a high yield (20-25 quintals/acre) so it covers 3 years of the ancestral production even if there is a loss. Ancestral seeds were flood resistant but low yield (7-8 quintals/acre)."
Fertilisers: we use more fertilisers (10kg) than before (2-3kg), those who don't have much money might only use 7kg (and have a yield of 15 quintals/acre).
Livestock: cows - *started after the creation of the milk society 7 years ago, breed Jersey: gives more milk but requires more care than local breeds* -, goats.
Water: hand pump, river.
Road: concrete, mud. Important if a cyclone/flood is coming. Concrete road is not damaged by it.
***Kutcha* house** vs. *asbestos* house.
Human resources: youth men are unemployed, they are not interested in doing agriculture work and the education level is low. So they chose to go outside (seasonal migration).

C.4.1.2 For women

Agricultural land
Livestock: cows, goats
SHG groups (2): 10 members in each group, monthly meetings (each member pay 30 Rs/month, any member can take a loan when they need). Activities: cow farming, 7 cows in each group –> we milk them and sell to cooperative society, price depend on fat level. Cows are not grazing outside, they purchase cow food from the market and give also paddy straws and rice water. Each member take individually part of the money from cow milk.
Water: river (salt water) and 2 tube-wells.

Issues. Communication (road) => during flood time, it is painful and dangerous to go to the market.
No water irrigation for agriculture.
Poor quality housing (*kutcha* house).
No latrine facilities.
Would like to have more income-generating activities to support their families (within SHG groups).

Money-use. Money from loans or cow milk => we spend on household consumption. Men are in charge of handling that money.

C.4.2 Livelihood categorisation and wealth ranking

Everybody has *kutcha* house except 1 household who have *asbestos*.

Dynamics of socio-economic categories. Categories are quite constant but some changes can happen

Table C.5: Wealth ranking for Machhagan.

Category	Characteristics
Medium 6 households	- agriculture land (1 acre) - livestock (2-4 cows) - seasonal/all-year migration (on their own, to factories) - **issues:** not getting regular wages, disasters (floods)
Poor 10 households	- share-croppers - livestock (2-3 cows, 4-5 goats) - daily-wage labour - **issues:** not getting daily wage labour regularly
Very poor 6 households	- landless - daily-wage labour - livestock (1-2 cows) - old people, widows, disabled persons

Medium $\rightsquigarrow$ *Low:* income is constant but the family grows in size and market prices increase, no income and have daughters in age of marriage => have to sell land.

C.4.3 Seasonal calendar

Loans: those who have agricultural land take loans from credit societies every year to buy seeds, fertilisers etc. They never take loans over 5,000 Rs because they fear that they can't repay. Also, for bigger loans, banks would ask for a mortgage but they don't have one.

Table C.6: Seasonal calendar for Machhagan.

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Monsoon						⊙	⊙	⊙				
Water scarcity	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙		⊙	⊙	⊙
Kharif cultivation	H						T	T	⊙	⊙	⊙	H
Rabi cultivation	H	H								T	T	⊙
Food scarcity									⊙	⊙	⊙	
Grazing scarcity								⊙	⊙	⊙	⊙	⊙
Selling livestock	-	-	A	L	L	-	Y	E	A	R	-	-
Incomes	⊙	⊙										
Expenditures										⊙	⊙	
Loans						⊙	⊙			⊙	⊙	

C.4.4 Impact chain of natural hazards

Crop loss: 1999: super-cyclone
Between 2000 and 2013: 5-6 times floods with loss of all *kharif* production
2013: Phailin cyclone
2014: 60% loss (drought)
2015: 60% loss (drought)

Floods. During flood, our mobility pattern stops. Before a flood comes, we move the cows to the other side of the road and we still sell the milk During flood, we stay in the school premises. We lose our *kutcha* houses every year. We usually rely on government relief and on milk sales and daily wages. On a *good year*, if we get extra rice then we store it in case of flood next season.

C.4.5 Photovoice



Figure C.24: Daily life. [Women] Women are in charge of cooking duties in the household. Here women are preparing dinner.



Figure C.25: Livestock. [Women] Goat is one of the main livestock that households own in the village. We can sell it if necessary or we eat them during festivals (left). Men are in charge of milking the cows. We milk cows during 7 months per year (right).



Figure C.26: Soil erosion. [Women] Before, there was no river here. It was only agricultural lands there, this branch river has appeared maybe 50 years ago. We've lost a great part of our agricultural lands.



Figure C.27: Cow dungs. [Women] Cowdung are essential for cooking, we use it as fuel. We first prepare cakes (left) and then we store them in piles so they can dry (right).



Figure C.28: Daily life. [Women]



Figure C.29: Paddy processing. [Women] After harvesting, we have to process the paddy. We're doing this from December to May when temperatures are high. Then we keep paddy in our houses with polythene on it.



Figure C.30: Village road and houses. [Women]



Figure C.31: Wasteland. [Men] Personal land with no agricultural use because of the proximity to river (salinity intrusion). It is used for animals grazing and preparing cow dung cakes.



Figure C.32: Struggle of elderlies. [Men] An old man who lost his kharif crop due to water scarcity. After crop harvesting, we usually do rabi cultivation (peanuts or pulses) on fertile land, with "potu mud" after flood (left). Old man who is very vulnerable. He is a BPL, his sons are doing wage labour but are not taking care of him and don't give him anything (right).



Figure C.33: Landless relying on livestock. [Men] Landless household with 3 daughters. They didn't inherit from any land. The man is doing daily wage labour and they rely on cow milk production as well.



Figure C.34: Cow feeding. [Men] We feed the cows with special food bought at the market and also paddy straw that we mix with rice water or milk water.



Figure C.35: River fishing. [Men] People are going to fish for self-consumption. They don't go far, they just use nets on the riverside. We're not selling because we only get a small amount of fish catch (1kg/catch maximum, not everyday).



Figure C.36: Fishing in the pond. [Men] Every year in summer, we use motor-pumps to dry the pond so we can catch the fish that is inside. Then we share the fish catch between all the families of the village.



Figure C.37: Wasteland. [Men] Personal land with no agricultural value because of the proximity to river (salinity intrusion). It is used for animals grazing and preparing cow dung cakes.



Figure C.38: Cow milk production. [Men] People who milk the cows are from a different caste. Households who don't know how to milk rent their services. They are from a different village and take 300Rs/cow/month (left). Man bring the milk to the society to sell it. The society is located at a distance of 500m of the village (right).

C.5 Tanra

Village: Tanra
Panchayat: Tulanga
Block: Tirtol
Total households: 95
Total population: 350

C.5.1 Resource mapping

Agricultural land: main livelihood, *kharif* and *rabi* (pulses: green and black gram, dal).
Canal for irrigation: built more than 50 years ago.
SHG groups (7): linked with a SHG cooperative, savings and credit activities, take loan from group when necessary, no income-generating activities.
Water supply collection: built more than 25-30 years ago thanks to someone who was a political leader in the village.
Schools: primary and high school.
Health: primary health centre (2km).
Political: block office (2km).
Other: electricity, market (3km) and small tourist temple.

Issues. Lack of road communication (not good quality) => difficult during rainy season. Difficulties in drainage of roads. Although there is a canal, difficulties of irrigation to agricultural land.

C.5.2 Social mapping

Youth club. Agricultural land equal everywhere (both *kharif* and *rabi*). After paddy cultivation, the canal is usually dry. No irrigation during *rabi*, only rainfed but no weather problems. Irrigation during *kharif* => drip water. Paddy sold if marriage/build house/repay loan/disease. Seeds: block subsidised, *Borsa Kalachampa 1018*, started to use after super-cyclone 1999.

C.5.3 Livelihood categorisation and wealth ranking

10% of households have livestock for self-consumption only. *"Nobody is going down between categories, only people going up."*

C.5.4 Impact chain of natural hazards

Crop loss: 1955; 1982; 1999. If heavy rain –> water logging (only during *kharif*); 20-30% loss every year

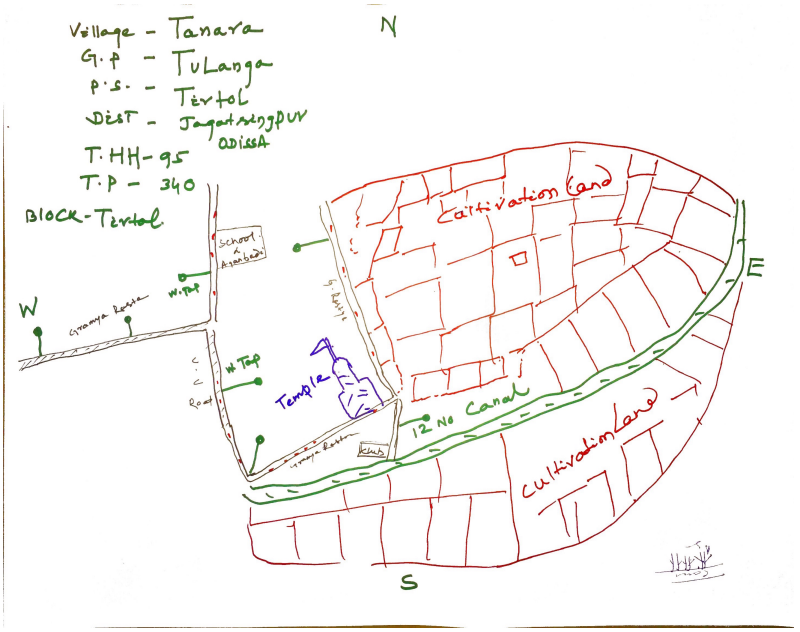


Figure C.39: Social map for Tanra.

Table C.7: Wealth ranking for Tanra.

Category	Characteristics
Better-off 15 households	- government employment / service - agricultural land (3-4 acres) - *pucca* house - livestock
Medium 50 households	- agricultural land (0.5-1 acre) & share-cropping - daily-wage labour - all year food security - mixed house (*asbestos, kutcha*
Poor 20 households	- share-croppers - seasonal migration (construction) - sometimes daily-wage labour - *kutcha* house
Very poor 10 households	- daily-wage labour - landless - *kutcha* house - widow, disabled people

Table C.8: Seasonal calendar for Tanra.

Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Monsoon						⊙	⊙					
Water scarcity				⊙	⊙							
Kharif cultivation	H						T	T	T	⊙	H	H
Rabi cultivation	T	T	H	H								
Food scarcity	N	O	T	-	R	E	L	E	V	A	N	T
Grazing scarcity					⊙	⊙						
Selling livestock	N	O	T	-	R	E	L	E	V	A	N	T
Incomes	⊙	⊙	⊙	⊙								
Expenditures					⊙	⊙						
Loans					⊙	⊙						

C.6 Konarpur

C.6.1 Resource mapping

85 households, population 450. No general castes in the village. Scheduled castes (22 households) (daily wages, agriculture share croppers). Other backward castes (63 households).



Figure C.40: Resource map for Konarpur.

C.6.1.1 For women

Agriculture: paddy cultivation but flood is the major problem because of crop loss. They lose crops every year. Two to three times flood between July and September. No embankment between river and field and no canals to drain the water. One motorpump for irrigation (water panchayat scheme). They sometimes lose *rabi* cultivation (paddy) because of water scarcity.
River: branch river from 2-3 rivers, if overflows it becomes flooded. In summer there is no sufficient water coming. We have water tanks since 2006 (repaired in 2016).
Labour migration: migration to Gujarat and Kerala in cotton factory companies and for construction labour. Men only, for 1 year migration or seasonal.
Water: 5 tube-wells but they become dry in summer.
Pre-school in the village, road, electricity.
SHG groups: 3 SHG in the village, doing money collection and savings only, not doing any income-generating activities.
Livestock: cow and bullocks for agriculture.
Some households got a personal loan from SHG and Gramobank for cow farming (milk), betel leaves farming.

Issues. No cyclone shelter, no cemetery.
Latrine is a major issue for women: they have informed the block but they haven't done anything yet, they have applied for individual latrine for each house (governmental scheme).

Tube-wells become dry in summer (April/May)
Problem of youth unemployment.

C.6.1.2 For men

Land: agricultural (50 acres), lay (3 acres), grazing (5 acres).
Water: 3 government tube-well (one not functioning).
Schools: 1 project primary school and 1 pre-primary.
Milk cooperative society: 60 cows, funded by villagers. Those who have cows can become member, selling milk to the market.
Livestock: 40 goats/sheeps for selling.
Housing: 15 *pucca* houses (cement/concrete); 10 *asbestos* house (metal sheets); 60 *kutcha* house (mud and bamboo).
Latrine: 10 households have individual latrine structure.
Irrigation infrastructure.
Road communication to the market.

Issues. Drinking water, latrine, cemetery, cyclone shelter, electricity (for the last 10 years but all households are not connected yet), hospital is far (11 km, Pipili), dam/reservoir to store and preserve water of the river (*Dhanua*) because the river becomes dry during summer.
Need of permanent house structures: they applied for the governmental scheme (100,000 Rs for BPL families) but still haven't got access. They also want a road structure from village to river, want loans from banks (only richer have access to lands at the moment), want a community house in which they can have meetings/discuss village development issues.
Their political leader is from a different party than panchayat leader so they don't access their entitlements and governmental schemes.

C.6.2 Livelihood categorisation and wealth ranking

Total number of households: 85

C.6.3 Impact chain of natural hazards

In the case of crop loss, they take local loans or go for seasonal migration. The socio-economical categories are flexible: in the case of recurrent crop loss medium households might have to do distress sale and move to the *poor* category. Same case can happen in the case of marriage. If there are many daughters in the household, they have to sell land to pay for the marriage and the parents become landless.

Table C.9: Wealth ranking for Konarpur.

Category	Characteristics
Better-off 4 households	- government employment - own land: 1-3 acre - own cattle - paddy harvest for 12 months - *pucca* house
Medium 15 households	- agriculture for main livelihood - two motorbikes - 8-10 months of food - *asbestos* house - lack of governmental schemes
Poor 61 households	- share-croppers - daily wage labour - paddy for 6 months - *kutcha* house - 6 months migration - no latrines, not getting wages every time
Very poor 5 households	- landless - disabled - very old *kutcha* house - food scarcity almost all year

C.6.4 Photovoice



Figure C.41: Problem of access to pensions. [Women] Disabled woman (blind) who deserves entitlements but she still haven't got any. She doesn't have any land and live in a kutcha house (left). Widow who doesn't have access to her pensions (right).



Figure C.42: Livestock. [Women] Cow shed (left) and cowdung cakes for cooking fuel (right).



Figure C.43: Water pond. [Women] The pond is full of grass so we can't go fishing nor bathing in the pond.



Figure C.44: Problem of access to water and latrine. [Women] Two tube-wells are not functioning out of 5 (left). Individual latrines for only one household in the village (right).



Figure C.45: Poverty. [Women] BPL household (left) and disabled household (right).



Figure C.46: Agriculture. [Women] Betel leave cultivation structure that was partly destroyed by cyclone (left). Rabi cultivation (right).



Figure C.47: Agriculture. [Men] Rabi crop with pulses (left). Betel leave cultivation (right).



Figure C.48: Agriculture. [Men] Irrigating the seed nursery for paddy kharif cultivation.



Figure C.49: Irrigation. [Men] Irrigation motor from the river. Only used for *rabi* irrigation (pulses) and seed nursery. They can't use it for drainage during kharif floods because it is fixed.

C.7 Dakhinaveda

Village: Dakhinaveda
Block: Rajanagar
District: Kendrapara
80 households

C.7.1 Resource mapping

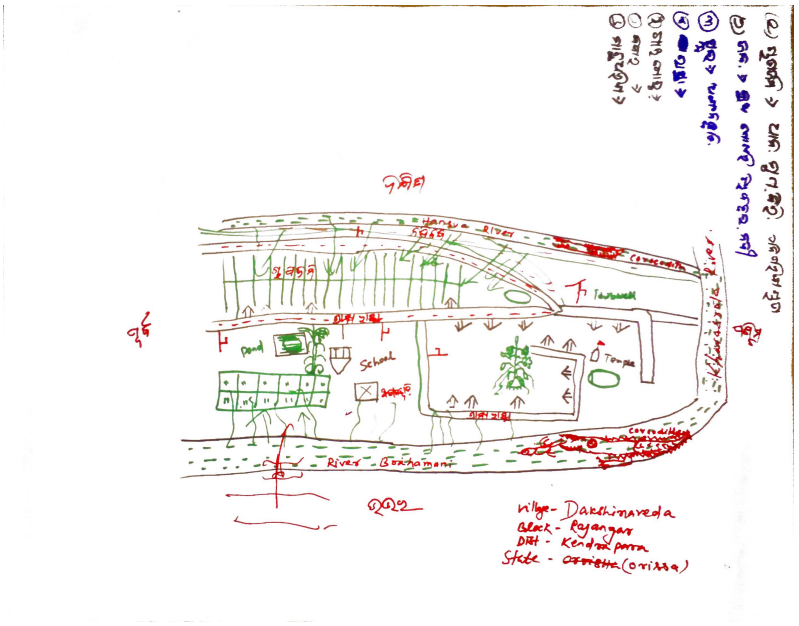


Figure C.50: Social map for Dakhinaveda. By men

C.7.1.1 For women

Agriculture: facing saline water => damage cultivation. *kharif* 2015: lost 50% of harvest because of rain scarcity and saline water (usually 4 quintals/acre but this *kharif* only 2 quintals/acre). Kitchen gardening for self-consumption.
Livestock: cows, sheeps, difficult to provide food because of saline water, they keep the animals at home because of the crocodiles in the river.
Water: scarcity of drinking water is the main issue (every summer), 5 tubewells, 2 are not functioning, river surrounding the village (salt water).
Social amenities: school up to 5th class, no medical facility (need to travel to Kendrapara HQ $\approx 60km$).
SHG groups: 6 groups of 10 members each, do savings and loans, got access to scheme *Mobadi Yojana* (Odisha Rural Livelihood Mission) for kitchen gardening: each member got 1,200 Rs for seeds. Got loans from SHG federation (for internal loan landing).

Issues. No latrine facilities and scarcity of drinking water every summer. The major livelihood depends on agriculture but there are no irrigation facilities for *rabi* cultivation and we are facing water scarcity. SHG groups: want support for income-generating activities.

C.7.1.2 For men

Agriculture: paddy (sold to reimburse the loans they took, or for any other expenses, such as medical condition, etc.), rabi crop (10% don't do *rabi* because they are not interested or men migrate, so they suffer from a lack of human resources).
Vegetables (self-consumption), rainfed, no irrigation system (salinity in river).
Seeds: now use block seeds for the last 2 years (Sorma Sub1) => more production, flash flood resistant.
Fertilisers: some farmers use block seeds.
Water: river: crocodiles, no embankment on the river => flood of agricultural land, saline water Saline water => no irrigation possible **School:** used as cyclone shelter
Road: communication, to save their lives during flood, reaching block officials, market.
Livestock: graze on crop residuals from *rabi* cultivation
"Every household has cows"
80% cows, 20% goats, some households sell milk (local sale).
Local market
Fishing: for self-consumption.

Job cards. Almost 80% of the population have it. For one day of work, the government gives 150 Rs but if a person works somewhere else, they get 300 Rs per day. Also, to get the government's money for your work, you have to wait and it has to go through the banking system. That's why most of the people prefer to work outside of this scheme.

Issues. The main problem is that we have less agricultural land now (we lost land to the river because of erosion) so we have no more work and future in farming. Drought and floods during kharif season. No irrigation system due to saline water of Brahamani river (from December to June). No embankment structure for the Brahamani river –> agricultural land gets flooded.

C.7.2 Livelihood categorisation and wealth ranking

C.7.3 Seasonal calendar

Loans: for ploughing (rent tractor - 1 in the village), fertilisers, hire labour work, water pump (July to November).
Loan reimbursement: usually small amounts to reimburse, migration.
Food scarcity: in the case of food scarcity, some members go on migration or take loans (State Bank). They don't sell animals because they only have very few.

Table C.10: Wealth ranking for Dakhinaveda. By women.

Category	Characteristics
Better-off 2 households	- government employment - **issue:** water scarcity
Medium 2 households	- 10 months of food security - *indra awas* scheme house - **issue:** water scarcity, flood, salinity intrusion
Poor 18 households	- 6 months food security - *kutcha* house - **issue:** water scarcity, salt water, lost their land to the river
Poor 60 households	- daily-wage labour - very poor quality *kutcha* house

Table C.11: Wealth ranking for Dakhinaveda. By men.

Category	Characteristics
Better-off 5 households	- government employment (teachers, block HQ) - *pucca* house - tractor and 1-2 cows - agricultural land (1 acre, before 5 but under water now) - *kharif* and *rabi* - **issue:** communication (road), water irrigation
Medium 20 households	- working outside village (all-year migration) - send remittances every 2-3 months - agricultural land (before) but now share-croppers - food for 1 year - *kutcha* house - **issue:** not getting regular wage, no irrigation for *rabi,* floods
Poor 30 households	- share-croppers., food for 6 months - seasonal migration - *kutcha* house or *indra awas* scheme - **issue:** drinking water, flood and drought, need cyclone shelter
Poor 25 households	- landless, 3 months food security - daily-wage labour - very poor quality *kutcha* house - **issue:** food scarcity, drinking water, no government scheme

C.7.4 Impact chain of natural hazards

Recovery time: 1 year **Kharif:** flood
Rabi: salinity
Phailin (2013): crop loss –> seasonal migration, sold land and livestock, sold jewellery, loans from bank.
Good production (2014) Drought (2015) –> a lot of migration (Bangalore, Dubai)

Before, everyone had their own land but now the river is bigger. It has led to land erosion so now we have less agricultural land. The river used to be 3 km far from the village (1971) but now

Table C.12: Seasonal calendar for Dakhinaveda.

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Monsoon						⊙	⊙	⊙	⊙	⊙	⊙	
Water scarcity			⊙	⊙	⊙							
Kharif cultivation	H	H					T	T	⊙	⊙	⊙	⊙
Rabi cultivation	T	T	H	H								T
Food scarcity										⊙	⊙	
Grazing scarcity		⊙	⊙	⊙	⊙							
Migration				⊙	⊙							
Incomes	⊙	⊙										
Expenditures	⊙					⊙	⊙					⊙
Loans							⊙	⊙				

it is far from less than 200 m. In 2002 the Government built a stone embankment. The river shifted, 150-200 years ago the river was more than 3 km far. Now, 10 villages are under water; rich people migrated to different *panchayats* and the poor migrated on the road near this village. When there is a flood, we migrate to our relatives or to the Red Cross structure. We usually come back once the flood is over, maybe after 15 days.

Good season: –> In the case of good season, we're not selling paddy to coop/government because the price is very low (800 Rs/quintal). What they get is marginal and they only use paddy sale to pay for school fees.

Migration: –> Before, five people were going for migration, but now, starting from 17 years-old, everyone start to migrate. Now, migration is a must. For example, I am doing agriculture and my son is going for migration. Whatever money we get from his work, we then invest it in agriculture.

C.7.5 Photovoice



Figure C.51: Funeral ceremony. [Women] Funeral wok (after 10 days, family cooks for all the village).



Figure C.52: Kutcha house. [Women] Every year, we have to rebuild the roof. We know that it's gonna be destroyed by floods but we have no other options.



Figure C.53: Kitchen garden irrigation. [Women] Sometimes, we find sweet water in the river. So we collect water to irrigate our kitchen garden.



Figure C.54: Cow feeding. [Women] Man collecting grass from the riverside to feed the cows (upper left). Woman feeding cow with rice water and milk (upper right). Woman collecting straw to feed the cows (lower left). Cow shed (lower right).



Figure C.55: Daily life. [Women] Picking coconut tree leaves for shade and for making brooms (cleaning) (left). Collecting water from the river from the tube-well for house consumption (right).



Figure C.56: Paddy processing. [Women] Women drying paddy before rice shelling.

C.8 Lokanathprasad

Village: Lokanathprasad
Block: Rajanagar
District: Kendrapara
Total households: 40
Total population: 250

C.8.1 Resource mapping

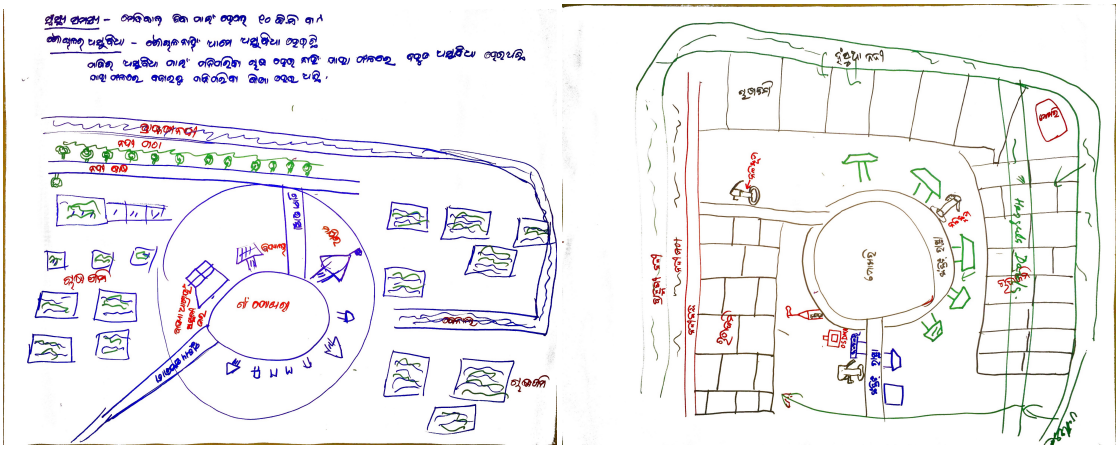


Figure C.57: Social map for Lokanathprasad. By women and men

C.8.1.1 For men

Water: pond, hand-pump, river, tube-well (1 not working, 2 working)
Cyclone shelter
School
River embankment
Agricultural land: rainfed only, irrigation not possible all the time because the river is salty, 5 water pump in the village, bought by individuals. Renting price: 150 Rs/hour.
kharif: paddy (mainly self-consumption)// use block-subsidised seeds (*Puja Sworno B20*) since 2010 => better production and 2-3 days flood resistant.
Before those seeds, we were not using fertilisers, but since we use the new variety we use 20 kg/acre. Ancestral seeds were not productive enough.
rabi: pulses, vegetables. Harvest time depend on how early people sow => those with water pump started earlier **Road:** concrete and mud **Trees and livestock**
Houses: concrete and asbestos.

Issues. Water enters the agricultural fields.

C.8.2 For women

Agricultural land: paddy, gram dal, vegetables.
Road: *kutcha*
Livestock: bullocks, cows, goats, sheeps, hens, ducks –> personal consumption only.
Embankment
Water: 3 tube-wells functioning for drinking water.
Cyclone shelter
School: up to 5th standard.
Trees: for decreasing wind and to strengthen the embankment.
Electricity
SHG groups (2): savings & credit, tried kitchen gardening but stopped because of flood and salt water, have never got any loans from bank.

Issues. Floods $\rightsquigarrow$ loss of paddy. Salt water and drought during summer (*rabi* cultivation). *Kutcha* road –> difficult to go to the market (3 km distance) if they want to sell/buy vegetables. Lack of health facilities (have to go to Rajanagar $\approx 10km$. Latrine issues and drinking water scarcity.

C.8.3 Livelihood categorisation and wealth ranking

Table C.13: Wealth ranking for Lokanathprasad.

Category	Characteristics
Better-off 5 households	- own agricultural land (2-3 acres) - 8-10 months migration (only some members) - own water-pump - *kutcha* house
Medium 15 households	- share-croppers - daily-labour activities - migration 6-7 months - *kutcha* house - livestock: 1-2 cows - **issues:** depending on landlords, daily labour, agricultural loss // problem of money synchronisation (when they need they don't get any)
Poor 10 households	- daily-labour activities in nearby villages - share-croppers - usually no migration (only 1 man) - **issues:** not enough daily labour work and agricultural loss
Very poor 10 households	- daily labour - widows (female-headed households) - persons with physical handicap - **issues:** not able to work

Share-cropping. For 1 acre of land rented, the farmer has to give half of the harvest to the owner. Usually the owner is from outside the village.

Change of socio-economical category. *Medium* $\rightsquigarrow$ *Poor:* whenever there is a crisis: someone dies in the family or there are some severe health issues. For example, one man was sick, he got operated but was the only earning member as his kids are very young. Before he was farming but now he can't because he must take rest.
Poor $\rightsquigarrow$ *Medium:* when kids grow and become earning members by going outside to work. Leads to a better living style, can construct own house and if they find good land they might purchase it (very rare though).

Investment: It is better to spend our money on our own lifestyle because agriculture is not profitable anymore, especially for share-croppers.
Migration: use contractors (middlemen), sometimes take advance or they go on their own, usually one male member per household stays in the village.

C.8.4 Seasonal calendar

Loans: almost every year (April-May) to prepare for agricultural activities. From credit cooperative society (lower interest rates 2%). Difficult to get loan from bank (and higher interest rates 7%) Repay loan in 3 years usually.

Table C.14: Seasonal calendar for Lokanathprasad.

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Monsoon						⊙	⊙					
Kharif cultivation	H						T	T	⊙	⊙	H	H
Rabi cultivation	T	⊙	H	H							T	T
Food scarcity								⊙	⊙			
Grazing scarcity								⊙	⊙			
Migration	-	-	A	L	L	-	Y	E	A	R	-	-
Incomes		⊙	⊙	⊙	⊙							
Expenditures	⊙						⊙	⊙				⊙
Loans				⊙	⊙		⊙	⊙				

C.8.5 Impact chain of natural hazards

Land loss due to river submersion: before (50 years ago): 210 acres in the village, now: only 10 acres.
Crop loss: every year, loss of 10-20% at harvest because of drought

2011: 100% loss because of floods
2014: 80% loss because of cyclone Phailin
2015: 40% loss because of cyclone Urul

Coping strategies in the case of crop loss:
80-90% of people fo on migration (men only).
20-25% are selling cows for loan reimbursement and food.

Good season:
Some people sell paddy outside to repay loans, marriage, rent ploughing, buy fertilisers.
Members of credit cooperative at the bank sell to the cooperative society (need to have more than 2 acres).

Recovery time from crop loss:
1 year to recover if the next agricultural season is good.

C.8.6 Photovoice



Figure C.58: Forest plantation. [Women] Trees planted with the support of the NGO Pallisri to protect the village from strong wings.



Figure C.59: Land erosion. [Women] The river is eroding our agricultural land. The government has not taken any initiative but we need a stone embankment.



Figure C.60: Riverside grass. [Women] We don't use take advantage of this resource because we're going to lose it to the river. Also, cows cannot graze there because of the crocodiles.



Figure C.61: Agriculture. [Women] Woman collecting straws to feed the cows because they cannot graze outside (left). Man coming back from harvesting his field at the end of the *rabi* cultivation (right).



Figure C.62: Road and agriculture. [Women] Old road now submerged by the river for the last 10-15 years. Before the village was 2-3 km away from the river but now the river is at our doors. We use this road for agricultural purposes now such as storing our rabi crop (left) or drying cow dung cakes (right).



Figure C.63: Caste and livelihoods. [Women] Boats from another village used for fishing. Here in our village we don't fish because we are from a different caste. Fishing is not our occupation, it is the occupation of low-caste people.



Figure C.64: Land erosion. [Men] We have informed the block HQ and the water department. They came, they saw the situation but didn't do anything because our village leader is from a different political partie than the block leader. So there is no cooperation and we don't access anything from the government.



Figure C.65: Cyclone shelter and tube-well. [Men] The tube-well is functioning but is not in very good condition.

C.9 Ektala

C.9.1 Resource mapping

The village is 3 km far from the closest market (Chandapur) There are 4 self-help groups in the village (women only). There is a problem of water & sanitation. Problem of drought (especially this year): need irrigation Some families lack food for 4 months, others have food for the all year Facilities: drinking water, medical facilities, school and playground. School facilities are there but quality of education is not. They need irrigation facilities for agriculture and a deeper well They did not get access to subsidised seeds from the government; if they need seeds they go to the block head village

C.9.1.1 For women

Water resources: pond, tubewell, river. During monsoon we get water sufficiently. The rest of the days it is dry. Before, we used to have fish in the ponds. But not anymore (for the last 10-15 years) because of water scarcity.

Forest: for fuel/wood, shade/cool environment and grazing for goats.

Land: major resource, paddy cultivation June $\rightsquigarrow$ December.

Road communication: access to market but not concrete road, difficult to go to the village pond.

Domestic animals: cow for milk, dung for fertiliser. Bullocks for transport and ploughing, goat for meat (mutton).

Rabi cultivation: used to do rabi cultivation 10-11 years ago but they now stopped because of water scarcity and wild animals on the same field as paddy cultivation. Pulses: green gram, black gram, urad. Vegetables: bitterground, beans, tomatoes. Sunflower (for oil).

Public institutions: panchayat office nearby, primary school and high school.

Self-Help Groups: women empowerment (only women), 10 women in a group, collect money from members (100 Rs/member/month). They started SHGs by themselves, now there are 52 women involved in the village. Use money to invest into collective income-generating activities such as poultry, biscuits (sold at market) and pulse processing. Use money to give loans to members from which they get interests. They have bank linkages with the State Bank of India and got one training from the Rural Bank on how to keep a record and other administration activities.

C.9.1.2 For men

Water: pond, tubewell, well **Land:** agricultural land, forest **Houses:** 3 different types **Animals:** cows, bullocks, goats, poultry, sheeps

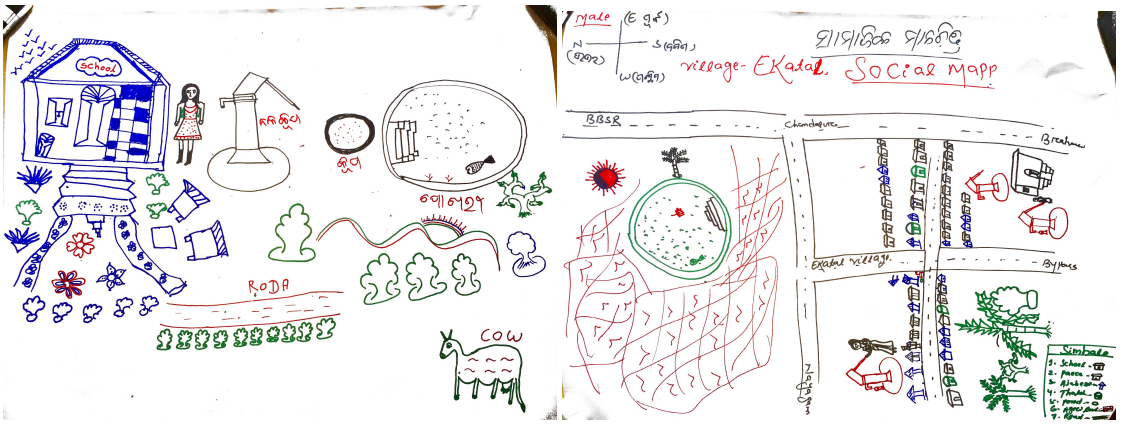


Figure C.66: Resource map for Ekatal by women (left) and men (right)

C.9.1.3 Difficulties

Water scarcity from January to April. Problems of drinking water and daily use Problems of rabi cultivation because of drought Sanitation: open-defecation, no latrines Cattle: not enough food for animals Within the last 10 years, there is no more monsoon in October/November. Before, we were doing transplantation in June/July/August.

C.9.2 Livelihood categorisation and wealth ranking

Mainly general caste, few Other Backward Castes (OBC). The majority of people depend on wage labour (nearby) and seasonal migration (to Bangalore, Nadapur, Gujarat) for construction work. Very poor and better-off are less affected by droughts than others because they don't rely on agriculture for their livelihoods.

Migration. We started migration around 15 years ago, gradually and it is increasing. Now that we go on seasonal migration (from December, for 7-8 months), our lifestyles have increased. We migrate more if there is a drought. During migration, women take care of the household.

C.9.3 Seasonal calendar

Selling animals is not constant, whenever they find food scarcity or they face needs, they will sell. *Kharif* harvest in December-January: they will sell part of their paddy and will get most of their incomes at this period. They take credits every year for preparing the *kharif* cultivation and to pay school for children. They will refund the loans in December/January with the incomes

Table C.15: Wealth ranking for Ekatal.

Category	Characteristics
Better-off 5 households *5%*	- own their cultivated land (5-6 acres) - government employee - 1 to 2 self-employed persons - two motorbikes - house made of bricks and cement sheets - own cattle: 5 cows
Medium 20 households *21%*	- own their cultivated land - one member working out of the state (all year) - cement and brick house - rabi cultivation (3-4 families only, vegetables) - kharif cultivation - own cattle: 3-5 cows, 2 goats
Poor 35 households *37%*	- do not own their cultivated land, share-croppers - daily labour - mud house - 20 families own cattle (around 2 cows)
Very poor 35 households *37%*	- daily labour - very old mud house - get pensions from government (disabled) - do not own cattle

Table C.16: Seasonal calendar for Ekatal.

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Monsoon							⊙	⊙	⊙			
Water scarcity				⊙	⊙	⊙						
Food scarcity						⊙	⊙	⊙				
Rabi cultivation		⊙	⊙	⊙								
Kharif plantation								⊙	⊙	⊙	⊙	
Migration	⊙	⊙	⊙	⊙	⊙	⊙						⊙
Main incomes	⊙		⊙	⊙								⊙
Main expenditures							⊙	⊙	⊙			

from paddy harvest. More expenditures in summer because of food scarcity, school fees, *kharif* preparation, festival time. Credits are taken from wealthier persons and relatives.

Impact chain of natural hazards. Drought during *kharif* season: 6-7 times in the last 10 years with around 75% crop loss. In the case of drought, family takes a decision, usually they go for more inter-state migration.

C.9.4 Photovoice



Figure C.67: Rabi season and drought [Women] I am one of the only one who cultivate vegetables during rabi. I have 3 acres and produce ginger, cucumber, sunflower and watermelon (left). Drought: we face drought during rabi cultivation that's why few people cultivate (right).



Figure C.68: Water. [Women] There are 3 tube-wells in the village, one in the school and two in the village. Only one tube-well gets dry. There is no regulation for the use of water but we only can use it for family use (left). There are five wells in total but they all get dry during summer. They are only for house-consumption purposes (right).



Figure C.69: Water tank. [Women] There is a governmental tank that is used for the water supply of Chanpur hospital (left). But the tank takes the water from the pond so our pond is dry now (right).



Figure C.70: Irrigation. [Women] Irrigation is very important for *rabi* crop cultivation. I have a well just for myself which allows me to cultivate, but I am the only one in the village.



Figure C.71: Pond. [Women] The pond is very muddy and is drying now. It is also polluted. The access is very bad now so it becomes difficult for us to go bathing in it.



Figure C.72: Cattle. [Women] We use cow dung for fertilisation. We have a common grazing area or lay land for cows, that we share with another village.



Figure C.73: School. [Women] There is a primary school in the village only for the children of this village (left) and also an integrated pre-primary school under construction (right).



Figure C.74: Land. [Women] This land is now private and was bought by someone who is not from the village for farming purposes. We think he wants to do a plantation in it (left). We get wood from the forest, which is about 1 km far from here (right).



Figure C.75: Agriculture. [Men] Highlands where they cultivate (left). Well that they built for kitchen gardening. They made it in the field but it is dry at the moment (right).



Figure C.76: Poor households. [Men] Kitchen in a poor household's house (left). Brick production unit. Poorest households work there as daily labourers. They earn 250 Rs/day (right).

C.10 Kusupalla

C.10.1 Resource mapping

For women

Note: women didn't know how to write, facilitator had to write for them.

Resources:
- Forest products: green leaves (to eat), *tunga* (root vegetable)
- Kitchen utensils
- Road "but not a real resource because in a very bad state"
- Water (ponds, wells, tube-wells)
- Agricultural land but only during monsoon time

The main resource for women is the forest for *tunga* and firewood.

Livelihood activities: - Goat farming: give birth twice a year, medicine ingestion twice a year to protect them from diseases, middlemen come and tell the price for one goat
- Poultry
- Cows: milk and cow dung for agriculture
- Cashew trees: planted but destroyed by elephants, 3 years before fruit production, production for 20 years, middlemen come to village and buy raw cashews, villagers know the price from the market (e.g. if 80 Rs/kg at the market, they will sell for 75 Rs/kg at the village)

Issues raised: - Droughts/water scarcity: well is not a resource because it is all the time dry. There is no point in saying that water is a resource because we suffer from water scarcity. We are not getting enough water: at the transition between winter and summer, in April, wells are dry; there is a scarcity of water. The rest of the year, we just have enough water for cooking but not enough water for crops.
- Wild animals (elephants, monkeys): we are not going to the dense forest because we fear elephants. We only are going to the nearby forest for *tunga*. The local government, instead of securing the forest, they are leading to the destruction of the forest. They are securing but they allow people to cut the trees.

For men

Natural resources: water resources (pond, tube-well, well, cross pont), land resources (agricultural land, lay land (for cattle grazing)), forest resources (land, fuel, vegetable, medicine), livestock (cow, goats, hens).
Community infrastructures: community road, community house, electricity.



Figure C.77: Resource assessment for Kusupalla by women (left) and men (right)

Livelihood activities: daily wages, cashews, goat farm, hens, fish pond (for self-consumption and also to sell some of them).
Agriculture: vegetables (black gram), paddy (only self-consumption), millet.

C.10.2 Livelihood categorisation and wealth ranking

Women's point of view

They used to be considered as Scheduled Tribes but not considered as ST anymore because of a change in the law that happened about 15 years ago. Now, children of mixed parents (one tribe, one not) don't get the tribal status. As ST, they used to get some job and land entitlements. They have funded an association with other villages in order to get their status back; advocacy to the government.

About remittances from migration: we don't have any option for business, we can't invest in anything. With the money, we repay loans or we buy paddy.

Wealth ranking: there are no better-off people, everyone has the same livelihood here:

- seasonal migration (younger generation) for livelihood search. Inter-State migration in Bangalore, Mumbai, Kerala
- drought-prone area but since it is a forest/hills/stone area, we do not get drought entitlement from the government
- threat of wild animals is now a major issue and upcoming hazard problem

Government scheme: all the households in the village have access to the "below poverty" card. With it, they get access to 5 kg of rice/wheat per head at the price of 1 Rs/kg and to 4L of oil per family every month.

C.10.2.1 Men's point of view

We go to Chandapun to sell vegetables such as tomatoes, cucumbers. Inter-state migration (to Mumbai, Bangalore) for construction labour. All young men (between 18 and 35 years old) go there for 6 months, mainly during summer (after sowing and coming back before harvest). They started this seasonal migration 10-15 years ago, mainly because of poor harvests and droughts. Men get an advance from middlemen before migrating, then they migrate and work. They get some more money after having worked a bit or at the end. They give the money to the family.

Table C.17: Wealth ranking for Kusupalla. By men.

Category	Characteristics
Medium 9 households *32%*	- own their cultivated land - food/paddy for 8 to 10 months - 1 to 2 self-employed persons - own cashew plantation - brick house with metal sheets (*pucca*) - vegetable cultivation - own cattle: 2 cows, 5 goats
Poor 15 households *54%*	- own their cultivated land - 4 to 6 months - go for seasonal migration - 1 employed in the family - some do vegetable cultivation - house made of mud (*kutcha*) - own cattle: 2 cows, 2 goats
Very poor 4 households *14%*	- do not own their cultivated land - paddy cultivation on low-land - wage/farm labour - do not have a cashew farm - small *kutcha* house - do not own cattle

C.10.3 Seasonal calendar

Seasonal migration is not constant, whenever they find food scarcity or drought they go for migration. Goat selling: all time according to their need/demand.

C.10.4 Timeline

Interview with a farmer 75 y.o., born in 1944.

In 1940s: The total number of households was 12, with livelihoods mainly based on domestic animals and forest. There were road and communication difficulties and didn't have access to electricity. Their food diet was based on corn, millet, paddy, *salaga* wood, *adunga* food, honey and bamboo paddy. By then (and until 1950s), they were under the King's juridiction.

Table C.18: Seasonal calendar for Kusupalla.

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Monsoon					⊙	⊙	⊙	⊙	⊙			
Water scarcity	⊙	⊙	⊙	⊙	⊙							
Rabi paddy	⊙	⊙	⊙	⊙	H							T
Kharif plantation						S	S	⊙	⊙	⊙	H	H
Forest products									⊙	⊙		
Cashew sale		⊙	⊙	⊙								

In 1999: They got hit by the cyclone and got some candles from the government. However they didn't have too much access to these schemes because of political issues.

In 2008: Access to electricity.

In 2011: New seeds, got access to the Green Revolution through a governmental scheme. If you do line transplantation for rice you get 600 Rs/acre for fertilisers/seeds.

Since 2012: The head of village is form a different political party than the *panchamat* and have political differences. Thus they don't have much access to governmental schemes.

C.10.5 Impact chain of natural hazards

The main hazard is drought; there are big droughts every 2 to 3 years (last in 2011, before in 2009). When there is a drought, more people migrate (seasonal migration for work). The *poor and very poor* sell goats (if they have any) or contract loans. The *better-off* sell goats or cows.

Resilience time: example of a poor household with only 2 goats. If there is a drought, we will sell 1 or 2 goats. It will take 2.5 to 3 years to get back to normal. If we lose again our crops during this period, we will have to get a loan. When there is food scarcity, they sell goats or cashews to buy rice. Since 2000, the number of people has increased. There is no definitive migration, only seasonal.

C.10.6 Institutions and suggestions

For the past 2 years, NGO with Tata Foundation have worked on irrigation and have renovated two ponds and installed a tank and a tap water network. There should be an incentive from the government to develop: (i) irrigation facilities; (ii) market linkage (the closest is Janpur, 15 km); and (iii) promotion of income facilities.

C.10.7 Photovoice

Note: men took only 6 photos and did not come to discuss them because they were busy.



Figure C.78: Observation deck for elephant watching. [Women] We use this platform to check if there are any elephants near the village. Men and women take shift to monitor the elephants, and they ring a bell or give light signals if there are elephants.



Figure C.79: Paddy *rabi* crop. [Women] Paddy is the staple for the households here. For the *rabi* season, we transplant in December-January and harvest in May-June.



Figure C.80: Collecting water at the spring. [Women] When village wells are dry, we go outside the village to a spring to get water for home consumption. We created this spring source structure in order to store water.



Figure C.81: Carrying water to the village. [Women] Women are in charge of carrying water. The spring is down a hill, it is very tiring to carry the water. We usually go all the women together to get water at the spring source.



Figure C.82: Water quality of the spring source. [Women] The water quality of the spring source is not good, but we don't have any other option when there is water scarcity. We use this water for food and for bathing, but we don't have health issues with it.



Figure C.83: Animal husbandry. [Women] Better-off families have a couple of cows. We milk the cows every morning, we can't milk them more because they don't have access to appropriate food. If there is a drought, households can sell cows but usually we sell goats.



Figure C.84: Dung collection. [Women] Cows and goat dungs for fertilisation, all year long (kitchen garden and paddy crop). We share it even with those who don't have any cattle. Picture on the right shows a woman carrying dung to fertilise the garden.



Figure C.85: Kitchen gardening. [Women] The better-off households have a garden where they grow green leafs vegetables, tomatoes, lady's fingers, onions. During winter it is only for self-consumption and to share with other families. During monsoon season, part of it is sold at the market. Picture on the right shows a woman carrying dung to fertilise the garden.



Figure C.86: Cleaning. [Women] The water from the tube-well located within the village is full of iron. We can't use it for food consumption or for drinking. We use it for cleaning dishes, bathing and kitchen gardening. The quality of the water from the open-well is better, we can use it for drinking purposes. The picture on the right shows the cleaning of dishes using water, ash and sand because we can't afford cleaning products.



Figure C.87: Food consumption. [Women] Rice and potatoes are staple food.



Figure C.88: Education and self-portrait. [Women] Women are in charge of the household management and of the education of children.



Figure C.89: Housing construction. [Men]



Figure C.90: Recreation games and motorbike. [Men]



Figure C.91: Housing. [Women] Better-off households have a house made of bricks, with a roof made of metal sheets. Poor and very poor only have mud houses with a roof made of thatch. Left: Digging for the construction of a new house. Right: Example of a mud house.

APPENDIX D R scripts

D.1 Extracting phenology metrics

D.1.1 Compute WDRVI with quality checks

```
#################################################################
# Calculate WDRVI's and apply Quality Assessment masks
#################################################################

##### load library #####
library(raster)
library (tools)
library(tcltk)
library(compositions)

#----------------------------#
# band  centered  band_name
#----------------------------#
#  1     648 nm     Red
#  2     858 nm     NIR
#----------------------------#

#### indices formulas ####
# WDRVI  = ((a * b2 - b1) / (a * b2 + b1))
rm(list=ls())
a  <- 0.2

# set working directory
setwd("/Volumes/berchport/soton/mod09q1/coastal/")

# list files
lst <- list.files(pattern='.sur_refl_b01')
image.lst <- sapply(strsplit(lst, split='.', fixed=TRUE), function(x) (x[1]))
image.list <- sapply(strsplit(image.lst, split='_', fixed=TRUE), function(x) (x[2]))
rm(lst, image.lst)

#### band names ###
band <- c(".sur_refl_b01.tif", ".sur_refl_b02.tif")
```

```
### Quality band ###
quality <- ".sur_refl_qc_250m.tif"

### values to build mask ###
### values derived from quality assessment ###
qa.binary <- c('000000000000000','100000000000000','010000000000000','110000000000000',
'001000000000000','101000000000000','011000000000000','111000000000000','000000000001100',
'100000000001100','010000000001100','110000000001100','001000000001100','101000000001100',
'011000000001100','111000000001100','000000000000010','100000000000010','010000000000010',
'110000000000010','001000000000010','101000000000010','011000000000010','111000000000010',
'000000000001110','100000000001110','010000000001110','110000000001110','001000000001110',
'101000000001110','011000000001110','111000000001110')

qa.va <- c()
for(i in 1:length(qa.binary)){qa.va <- c(qa.va,unbinary(qa.binary[i]))}

#pb <- txtProgressBar(min = 0, max = length(image.list), style = 3)
pb <- tkProgressBar(title = "wdrvi quality", min = 0,max = length(image.list), width = 300)

for (i in 1:length(image.list)){
  ### set working directory for loop ###
  setwd("/Volumes/berchport/soton/mod09q1/coastal/")

  ############# bands as variables ####################
  b1 <- raster(paste('coastalMOD09Q1_', image.list[i], band[1], sep = ""))
  b2 <- raster(paste('coastalMOD09Q1_', image.list[i], band[2], sep = ""))

  #### compute indices #####
  WDRVI   <- ((a * b2 - b1) / (a * b2 + b1))

  #### build the mask ######
  qc <- raster(paste('coastalMOD09Q1_', image.list[i], quality, sep = ""))

  for(j in 1:length(qa.va)) {
    qc[qc == qa.va[j]] <- 1
  }
  qc[qc != 1    ] <- 0

  #### apply mask #######
  ### apply mask WDRVI ###
  WDRVImasked  <- qc * WDRVI

  #### save results ###
  #### save WDRVI ######
  setwd("/Volumes/data/wdrvi/coastal/")
  writeRaster(WDRVImasked, paste(image.list[i],"_WDRVI","_MOD09Q1", sep = ""),
        datatype="FLT4S", format = "GTiff",overwrite=TRUE)

  #### remove files from workspace ####
  ### remove bands ###
  rm(b1, b2)
  ### remove indices ###
  rm(WDRVI)
  ### remove quality band ###
  rm(qc)
  ### remove masked indices ###
  rm(WDRVImasked)

  Sys.sleep(0.1)
```

```
  #setTxtProgressBar(pb, i)
  setTkProgressBar(pb, i,
        label=paste("Loop",i,"(",round(i/length(image.list)*100, 0),"% done)"))
}

close(pb)
```

D.1.2 Remove WDRVI noise and outliers using spline smoothing filters

```
library(greenbrown)
library(parallel)
library(plyr)

setwd('/Users/tb2g14/Dropbox/soton/data/wdrvi/coastal/')
load("df_wdrvi_coastal_cleaned.RData")
df2 <- df[,3:length(df[1,])]

# spline
smooth <- function(x) {
  vi.smooth <- TSGFspline(ts(as.numeric(x), start = c(2000,8),
        end = c(2014,46), freq = 46))
  wdrvi <- list(vi.smooth)
  return(wdrvi)
}

#system.time(wdrvi.smoothed <- adply(df2,1,smooth))
#wdrvi <- wdrvi.smoothed[,685:length(wdrvi.smoothed)]

# pre-processing
cl <- makeCluster(detectCores())
clusterEvalQ(cl,c(library(greenbrown)))
clusterEvalQ(cl, smooth <- function(x) {
  vi.smooth <- TSGFspline(ts(as.numeric(x), start = c(2000,8),
        end = c(2014,46), freq = 46))
  wdrvi <- list(vi.smooth)
  return(wdrvi)
})
clusterExport(cl,'df2')

# parallel processing
system.time(wdrvi.smoothed <- parRapply(cl,df2,smooth))

# clean workspace
stopCluster(cl)
gc()

# structure
n <- length(wdrvi.smoothed)
wdrvi.df <- structure(wdrvi.smoothed,row.names = c(NA,-n),class='data.frame')
wdrvi <- data.frame(matrix(unlist(wdrvi.df), nrow=n, byrow=T))
colnames(wdrvi) <- colnames(df2[1,])
wdrvi <- cbind(df[,2:3],wdrvi)

rm(cl,n,wdrvi.smoothed,df,df2,wdrvi.df)
rm(smooth)

save.image('df_wdrvi_coastal_smoothed_spline.RData')
```

D.1.3 Extract start of season based on the temperature sensitive period

```
library(lubridate)

setwd('/Volumes/data/wdrvi/coastal/')
load('df_startseason_tsp.RData')
load('df_wdrvi_coastal_smoothed_spline.RData')

infr <- c()
for(i in 0:13){
  infr <- c(infr,41 + (i*46))
}
rm(i)

tsp[,2] <- tsp[,2] + infr[1] - 1
tsp[,3] <- tsp[,3] + infr[2] - 1
tsp[,4] <- tsp[,4] + infr[3] - 1
tsp[,5] <- tsp[,5] + infr[4] - 1
tsp[,6] <- tsp[,6] + infr[5] - 1
tsp[,7] <- tsp[,7] + infr[6] - 1
tsp[,8] <- tsp[,8] + infr[7] - 1
tsp[,9] <- tsp[,9] + infr[8] - 1
tsp[,10] <- tsp[,10] + infr[9] - 1
tsp[,11] <- tsp[,11] + infr[10] - 1
tsp[,12] <- tsp[,12] + infr[11] - 1
tsp[,13] <- tsp[,13] + infr[12] - 1
tsp[,14] <- tsp[,14] + infr[13] - 1
tsp[,15] <- tsp[,15] + infr[14] - 1


date <- names(wdrvi)
date <- sapply(strsplit(date, split='X', fixed=TRUE), function(x) (x[2]))

date <- gsub("\\.", "-", date)
date <- as.Date(date)
date <- date[2:length(date)]

start_tsp <- yday(date[tsp[,1]])

for (i in 2:length(tsp[1,])){
  start_tsp <- cbind(start_tsp, yday(date[tsp[,i]]))
}

start_tsp <- as.data.frame(start_tsp)
names(start_tsp) <- names(tsp)

save(start_tsp,file = 'df_startoftsp.RData')
```

D.1.4 Sum WDRVI over temperature sensitive period

```
setwd('/Volumes/data/wdrvi/coastal/')
load("df_wdrvi_coastal_smoothed_spline.RData")

df <- wdrvi[,2:length(wdrvi[1,])]

infr <- c()
```

```
extr <- c()

for(i in 0:13){
  infr <- c(infr,41 + (i*46))
  extr <- c(extr,85 + (i*46))
}
rm(i)

compute_tsp <- function(x){
  tsp2000 <- sum(x[which.max(x[1:40]):which.max(x[1:40])+4])
  tsp2001 <- sum(x[which.max(x[infr[1]:extr[1]]):which.max(x[infr[1]:extr[1]])+4])
  tsp2002 <- sum(x[which.max(x[infr[2]:extr[2]]):which.max(x[infr[2]:extr[2]])+4])
  tsp2003 <- sum(x[which.max(x[infr[3]:extr[3]]):which.max(x[infr[3]:extr[3]])+4])
  tsp2004 <- sum(x[which.max(x[infr[4]:extr[4]]):which.max(x[infr[4]:extr[4]])+4])
  tsp2005 <- sum(x[which.max(x[infr[5]:extr[5]]):which.max(x[infr[5]:extr[5]])+4])
  tsp2006 <- sum(x[which.max(x[infr[6]:extr[6]]):which.max(x[infr[6]:extr[6]])+4])
  tsp2007 <- sum(x[which.max(x[infr[7]:extr[7]]):which.max(x[infr[7]:extr[7]])+4])
  tsp2008 <- sum(x[which.max(x[infr[8]:extr[8]]):which.max(x[infr[8]:extr[8]])+4])
  tsp2009 <- sum(x[which.max(x[infr[9]:extr[9]]):which.max(x[infr[9]:extr[9]])+4])
  tsp2010 <- sum(x[which.max(x[infr[10]:extr[10]]):which.max(x[infr[10]:extr[10]])+4])
  tsp2011 <- sum(x[which.max(x[infr[11]:extr[11]]):which.max(x[infr[11]:extr[11]])+4])
  tsp2012 <- sum(x[which.max(x[infr[12]:extr[12]]):which.max(x[infr[12]:extr[12]])+4])
  tsp2013 <- sum(x[which.max(x[infr[13]:extr[13]]):which.max(x[infr[13]:extr[13]])+4])
  tsp2014 <- sum(x[which.max(x[infr[14]:extr[14]]):which.max(x[infr[14]:extr[14]])+4])
  letsp <- list(tsp2000,tsp2001,tsp2002,tsp2003,tsp2004,tsp2005,tsp2006,tsp2007,
        tsp2008,tsp2009,tsp2010,tsp2011,tsp2012,tsp2013,tsp2014)
  return(letsp)
}
system.time(tsp <- apply(df,1,compute_tsp))

n <- length(tsp)
tsp.df <- structure(tsp,row.names = c(NA,-n),class='data.frame')
tsp <- data.frame(matrix(unlist(tsp.df), nrow=n, byrow=T))
colnames(tsp) <- c(2000:2014)
rm(n,tsp.df)
head(tsp)

save(tsp,file='df_wdrvi_tsp.RData')
```

D.2 Detection of crop failure using BFAST

```
library(rts)
library(rgdal)
library(bfast)
library(tcltk)
path <- system.file("external", package="rts")

setwd('/Users/tb2g14/Dropbox/soton/data/wdrvi/')
df <- read.csv("df_wdrvi_mod09q1.csv",header=TRUE)
df2 <- df[,4:601]

total <- length(as.numeric(df2[,1])) ; anomalies <- c()
pb <- tkProgressBar(title = "bfast", min = 0, max = total, width = 300)

for (i in 1:total) {
  fit <- bfast(ts(as.numeric(df2[i, ]), start = 2002, freq = 46),
           h = (46*2/length(as.numeric(df2[1, ]))), season = "harmonic", max.iter = 2)
  ifelse(fit$output[[1]]$Vt.bp==0,
         anomalies <- c(anomalies,0),
         anomalies <- c(anomalies,length(fit$output[[1]]$bp.Vt$breakpoints))
  )
  Sys.sleep(0.1)
  setTkProgressBar(pb, i, label=paste("Loop",i,"/486734 (",round(i/total*100, 0)," %)"))
}
close(pb)

anomalies <- function(x) {
  fit <- bfast(ts(as.numeric(x), start = 2002, freq = 46),
               h = (46*2/598), season = "harmonic", max.iter = 2)
  ifelse(fit$output[[1]]$Vt.bp==0,
         anomaly <- 0,
         anomaly <- c(length(fit$output[[1]]$bp.Vt$breakpoints))
  )
  return(anomaly)
}

 bfast.anoms <- pbapply(df3,1,anomalies)
```

D.3 Geographies of livelihoods

Socio-Ecological System Profiling of Rural Communities - Data

Tristan Berchoux

November 2017

- 1 Loading data
  - 1.1 Loading .csv files
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- 2 Spatial analysis
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- 3 Save results

1 Loading data

The data required for the analysis here are in several different formats: text files (`.csv`), shapefiles (`.shp`) and raster (`.tif`), as well as data downloaded using R packages. The standard data needed for the analysis are population data (text files), administrative boundaries (shapefiles), amenities (text files and/or shapefiles) and land cover (raster).

First we will need to set the working directory.

```
setwd("/Users/tb2g14/Dropbox/soton/projects/p2_ambio/")
```

Now let's load all the required packages. Make sure they're loaded in this order.

```
library(raster)
library(sf)
library(tidyverse)
library(cowplot)
library(spocc)
library(rgdal)
library(fpc)
library(maptools)
library(mapview)
library(osmar)
library(osmdata)
```

1.1 Loading .csv files

We have some population data stored as a `.csv` file. These data are the tables from the Census of India 2011 at the Community level. These data were downloaded from Office of the Registrar General & Census Commissioner. Below we use the `read_csv` function from the `readr` package (included in the `tidyverse` bundle) to load this file and the `summary` function to inspect the contents.

```
census.df <- read_csv("data/tbl_census/village_amenities_mahanadi_2011.csv")
census.df <- data.frame(census.df)
```

The summary function allows us to inspect the contents of the dataframe, however the dataset is quite large so we're just gonna check the names of variables.

```
names(census.df)
```

```
##   [1] "ST_CODE"                 "ST_NAME"
##   [3] "DIST_CODE"               "DIST_NAME"
##   [5] "SDIST_CODE"              "SDIST_NAME"
##   [7] "VILL_CODE"               "VILL_NAME"
##   [9] "BLOCK_CODE"              "BLOCK_NAME"
##  [11] "GRAM_CODE"               "GRAM_NAME"
##  [13] "REF_YR"                  "SDISTHQ_NAME"
```

```
## [387] "AREA_SOWN"                  "AREA_UNIRRIGATED"
## [389] "AREA_IRRIGATED_TOTAL"       "AREA_IRRIGATED_CANAL"
## [391] "AREA_IRRIGATED_WELL"        "AREA_IRRIGATED_LAKE"
## [393] "AREA_IRRIGATED_WATERFALL"   "AREA_IRRIGATED_OTHER"
## [395] "TOWN_NEAREST"               "TOWN_DISTANCE"
```

1.2 Loading shapefiles

We are going to use the 2011 community boundaries for India. Downloaded from Bhuvan GeoServer We will be using both `sf` and `sp` packages for working with shapefiles. First, we will load the data using `st_read` and then convert it to an `sp` object:

```
village.sf <- st_read("data/fcl_admin/mahanadi/mahanadi_villages.shp")
```

```
## Reading layer `mahanadi_villages' from data source `/Users/tb2g14/Dropbox/soton/projects/p2_ambio/data/fcl_adm
in/mahanadi/mahanadi_villages.shp' using driver `ESRI Shapefile'
## Simple feature collection with 7456 features and 12 fields
## geometry type:  POLYGON
## dimension:      XY
## bbox:           xmin: 84.97032 ymin: 19.46461 xmax: 86.99878 ymax: 21.23928
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```
village.sp <- as(village.sf, 'Spatial')
```

Note that the function we use to read in the data provides us with information about the contents of the shapefile. This includes the kind of geometry (point, polygon); the bounding box (i.e. the maximum and minimum coordinated) and the projection of the data (more about this later). We can also use the `summary()` function to inspect the contents of the shapefiles.

```
summary(village.sf)
```

```
##     ogc_fid        objectid         mdds_vt      st        d
##  Min.   :   1   Min.   :     0   395807 :   3   21:7456   09:1323
##  1st Qu.:1870   1st Qu.:423257   408738 :   3             10:1554
##  Median :3736   Median :430984   394630 :   2             11:1297
##  Mean   :3735   Mean   :428824   395160 :   2             12:   1
##  3rd Qu.:5601   3rd Qu.:435500   395771 :   2             17:1562
##  Max.   :7468   Max.   :443358   395808 :   2             18:1719
##                                  (Other):7442
##        sd             vt01             vt_name     mdds_st   mdds_d
##  0007   :1057   01644800:   4   Gopalpur    :  24   21:7456   378:1323
##  0004   :1025   01656600:   4   Nuagan      :  24             379:1554
##  0003   : 890   01713600:   3   Haripur     :  18             380:1298
##  0005   : 828   02898200:   3   Gopinathpur :  15             386:1562
##  0002   : 740   01507500:   2   Gobindapur  :  14             387:1719
##  0001   : 583   01509700:   2   Raghunathpur:  14
##  (Other):2333   (Other) :7438   (Other)     :7347
##     mdds_sd             vt_11              geometry
##  02939  : 313   Gopalpur    :  24   POLYGON      :7456
##  02923  : 301   Nuagan      :  24   epsg:4326    :   0
##  02940  : 243   Haripur     :  18   +proj=long...:   0
##  03058  : 240   Gopinathpur :  15
##  02943  : 235   Gobindapur  :  14
##  03054  : 222   Raghunathpur:  14
##  (Other):5902   (Other)     :7347
```

1.3 Loading raster files

We will also be using some raster data in our analysis:

- Rice Cover Map 2010 500m derived from MODIS data. These data were downloaded from IRRI
- Land Cover Map 2010 500m derived from MCD12Q1 product of MODIS data. These data were downloaded in R using the `ModisDownload()` function of the `rts` package.

We will use the `raster()` function from the `raster` package to load these data, then outputting the contents will give us information about these data.

```
irri.img <- raster("data/img_lulc/irri_2010.tif")
values(irri.img)[values(irri.img) > 8] <- 0 ; values(irri.img)[values(irri.img) == 0] <- NA
irri.img
```

```
## class       : RasterLayer
## dimensions  : 2262, 2898, 6555276  (nrow, ncol, ncell)
## resolution  : 0.002105, 0.002105  (x, y)
## extent      : 81.38147, 87.48176, 17.80449, 22.566  (xmin, xmax, ymin, ymax)
## coord. ref. : +proj=longlat +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0
## data source : in memory
## names       : irri_2010
## values      : 1, 8  (min, max)
```

We are going to use the MODIS land cover to also create a forest layer `forest.img` where every forested pixel is set at a value of `1`, the rest is `NA`.

```
modis.img <- raster("data/img_lulc/modis_2010.tif")
forest.img <- (modis.img == 2 | modis.img == 3 | modis.img == 4 | modis.img == 5) ; values(forest.img)[values(for
est.img) == 1] <- 9 ; values(forest.img)[values(forest.img) == 0] <- NA
urban.img <- (modis.img == 9) ; values(urban.img)[values(urban.img) == 1] <- 10 ; values(urban.img)[values(urban.
img) == 0] <- NA
```

Now we can merge both the rice cover map with the forest layer. First we need to resample the forest raster to match resolution.

```
irri.img <- round(resample(irri.img, modis.img)) ; values(irri.img)[values(irri.img) == 0] <- NA
lulc.img <- merge(irri.img, forest.img)
lulc.img <- merge(urban.img, lulc.img)
lulc.img[is.na(lulc.img)] <- 0
```

1.4 Downloading data from online sources

We are going to use the `osmdata` package to download physical features data from the OpenStreetMap project.

First, we will need a bounding box to limit the records to those within our study area. Let's use our case study extent found in the administrative boundaries shapefile `odisha_village.shp`.

```
extent.box <- as_osmar_bbox(village.sp) %>% opq ()
```

We can then use the `osmdata_sf()` function from the `osmdata` package to download records for features of interest. OpenStreetMap represents physical features on the ground using tags attached to its basic data structures. Tags describe specific features of map elements and consist of two items, [a key and a value] (http://wiki.openstreetmap.org/wiki/Map_Features). For example, `amenity==marketplace` is a tag with a key of `amenity` and a value of `marketplace` which should be used on a way to indicate a place where trade is regulated, for example a square. The `osmdata` package also provides a function to convert the retrieved data to a list of `sf` object, one for each type of data feature (i.e. polygons, lines, points).

```
worship.sf <- osmdata_sf(add_osm_feature(extent.box, key = "amenity", value = "place_of_worship"))
industrial.sf <- osmdata_sf(add_osm_feature(extent.box, key = "landuse", value = 'industrial'))
aquaculture.sf <- osmdata_sf(add_osm_feature(extent.box, key = "landuse", value = 'aquaculture'))
```

Now let's download road networks.

```
trunk.sf <- osmdata_sf(add_osm_feature(extent.box, key = "highway", value = "trunk"))
primary.sf <- osmdata_sf(add_osm_feature(extent.box, key = "highway", value = "primary"))
secondary.sf <- osmdata_sf(add_osm_feature(extent.box, key = "highway", value = "secondary"))
tertiary.sf <- osmdata_sf(add_osm_feature(extent.box, key = "highway", value = "tertiary"))
```

Let's create the `sp` equivalent of each point of interest

```
worship.sp <- as(worship.sf$osm_points, 'Spatial')
industrial.sp <- as(industrial.sf$osm_points, 'Spatial')
aquaculture.sp <- as(aquaculture.sf$osm_points, 'Spatial')
```

1.5 Merging data

We are gonna merge the census dataframe `census.df` with our administrative boundaries `village.sp` by using the individual code of each village (respectively `ADMIN_VILL_CODE` and `mdds_vt`). Let's first make sure both are of the same class.

```
names(village.sp)[3] <- 'VILL_CODE'
village.sp$VILL_CODE <- as.numeric(levels(village.sp$VILL_CODE))[village.sp$VILL_CODE]
village.sp@data <- inner_join(village.sp@data, census.df)
village.sp <- village.sp[!is.na(village.sp$MRKT_AGRIMARKETSOC_AV),]
```

1.6 Extracting data

We are going to use the census data to extract the locations of different amenities and then create a new layer with their centroids by using the `gCentroid()` function, included in the `rgeos` package.

```
library(rgeos)
market.sp <- gCentroid(village.sp[village.sp$MRKT_AGRIMARKETSOC_AV == 1, ], byid=TRUE)
health.sp <- gCentroid(village.sp[village.sp$MED_HOSP_ALT_NB >= 1, ], byid=TRUE)
education.sp <- gCentroid(village.sp[village.sp$EDU_GVT_S_SCH_AV == 1, ], byid=TRUE)
transport.sp <- gCentroid(village.sp[village.sp$TRA_BUS_PUB_AV == 1, ], byid=TRUE)
communication.sp <- gCentroid(village.sp[village.sp$COM_POSTOFFICE_AV == 1, ], byid=TRUE)
water.sp <- gCentroid(village.sp[village.sp$WAT_TAP_UNTREATED_AV == 1, ], byid=TRUE)
bank.sp <- gCentroid(village.sp[village.sp$BANK_AGRISOC_AV == 1, ], byid=TRUE)
public.sp <- gCentroid(village.sp[village.sp$SOC_POLLSTATION_AV == 1, ], byid=TRUE)
recreation.sp <- gCentroid(village.sp[village.sp$SOC_COMCENTRE_AV == 1, ], byid=TRUE)
```

1.7 Plotting data

We can then plot the desired data using the package `mapview`.

```
mapview(irri.img) +  mapview(modis.img) + mapview(health.sp, col.regions = 'blue') + mapview(bank.sp, col.regions
 = 'green') + mapview(market.sp, col.regions = 'red') + mapview(trunk.sf$osm_lines, col.regions = 'black') + mapv
iew(primary.sf$osm_lines, col.regions = 'red')
```



2 Spatial analysis

2.1 Creating a friction-surface dataset

First we need to rasterize the different road layers we just downloaded. Let's create an empty raster that will be used as a base canvas for the rasterization process.

```
null.img <- raster(extent(modis.img), res =  0.01, crs=proj4string(modis.img))
```

We now have to coerce our simple features objects to Spatial* objects so we can use the `rasterize()` function from the `raster` package. Trunk roads in India have an average travel speed of 90km/h (0.67 min/km).

```
trunk.sp <- as(trunk.sf$osm_lines, 'Spatial')
trunk.img <- rasterize(trunk.sp, null.img)
values(trunk.img)[values(trunk.img) > 0] <- 0.67
```

Primary roads in India have an average travel speed of 70km/h (0.8min/km), secondary roads of 50km/h (1.2min/km) and tertiary roads of 30km/h (2min/km).

```
primary.sp <- as(primary.sf$osm_lines, 'Spatial')
primary.img <- rasterize(primary.sp, null.img)
values(primary.img)[values(primary.img) > 0] <- 0.85

secondary.sp <- as(secondary.sf$osm_lines, 'Spatial')
secondary.img <- rasterize(secondary.sp, null.img)
values(secondary.img)[values(secondary.img) > 0] <- 1.2

tertiary.sp <- as(tertiary.sf$osm_lines, 'Spatial')
tertiary.img <- rasterize(tertiary.sp, null.img)
values(tertiary.img)[values(tertiary.img) > 0] <- 2
```

Let's now merge the rasters of the different types of roads together. We are using the `merge()` function, which gives priority to the first input raster.

```
roads.img <- merge(trunk.img,primary.img)
roads.img <- merge(roads.img,secondary.img)
roads.img <- merge(roads.img,tertiary.img)
```

After getting the road network, we now have to assign travel time values to the different land covers. We are using the raster `modis.img` to which we assign new values stored in the first and third columns of the table `modis_legend.csv` , by reclassigying the raster data.

```
legend_modis.df <- read_csv('data/img_lulc/modis_legend.csv')
rcl <- legend_modis.df[,c(1,3)]
lulc_tt.img <- reclassify(modis.img, rcl)
rm(rlc)
```

```
## Warning in rm(rlc): object 'rlc' not found
```

Now we can merge the road network with the land cover travel time. But we first need to resample our roads raster to a similar resolution than the land cover. This is done by using the `resample()` function.

```
roads.img <- resample(roads.img, lulc_tt.img, 'bilinear')
friction.img <- merge(roads.img, lulc_tt.img)
```

2.2 Distance to main amenities

We are going to use the gdistance package to compute distances to main amenities. We first create a transition layer (permeability instead of friction) using the `transition()` function.

```
library(gdistance)
transition.img <- transition(friction.img, function(x) 1/mean(x), directions = 4)
transition.img <- geoCorrection(transition.img)
```

Now that we have a transition layer, we can compute the accumulated cost of travelling to different types of amenities and services by using the `accCost()` function.

```
market.img <- accCost(transition.img, market.sp) ; values(market.img)[values(market.img) == Inf] <- NA
health.img <- accCost(transition.img, health.sp) ; values(health.img)[values(health.img) == Inf] <- NA
education.img <- accCost(transition.img, education.sp) ; values(education.img)[values(education.img) == Inf] <- N
A
transport.img <- accCost(transition.img, transport.sp) ; values(transport.img)[values(transport.img) == Inf] <- N
A
communication.img <- accCost(transition.img, communication.sp) ; values(communication.img)[values(communication.i
mg) == Inf] <- NA
water.img <- accCost(transition.img, water.sp) ; values(water.img)[values(water.img) == Inf] <- NA
bank.img <- accCost(transition.img, bank.sp) ; values(bank.img)[values(bank.img) == Inf] <- NA
public.img <- accCost(transition.img, public.sp) ; values(public.img)[values(public.img) == Inf] <- NA
recreation.img <- accCost(transition.img, recreation.sp) ; values(recreation.img)[values(recreation.img) == Inf]
<- NA

worship.img <- accCost(transition.img, worship.sp) ; values(worship.img)[values(worship.img) == Inf] <- NA
industrial.img <- accCost(transition.img, industrial.sp) ; values(industrial.img)[values(industrial.img) == Inf]
<- NA
aquaculture.img <- accCost(transition.img, aquaculture.sp) ; values(aquaculture.img)[values(aquaculture.img) == I
nf] <- NA
```

In order to profile our communities, it is important to have an effort value at the village-level. This is done by extracting an average value at the community level thanks to the function `extract()` of the `raster` package.

```
village.sp$market <- as.numeric(raster::extract(market.img, village.sp, method = 'bilinear', fun = mean, na.rm=TR
UE))
village.sp$health <- as.numeric(raster::extract(health.img, village.sp, method = 'bilinear', fun = mean, na.rm=TR
UE))
village.sp$education <- as.numeric(raster::extract(education.img, village.sp, method = 'bilinear', fun = mean, n
a.rm=TRUE))
village.sp$transport <- as.numeric(raster::extract(transport.img, village.sp, method = 'bilinear', fun = mean, n
a.rm=TRUE))
village.sp$communication <- as.numeric(raster::extract(communication.img, village.sp, method = 'bilinear', fun =
mean, na.rm=TRUE))
village.sp$water <- as.numeric(raster::extract(water.img, village.sp, method = 'bilinear', fun = mean, na.rm=TRUE
))
village.sp$bank <- as.numeric(raster::extract(bank.img, village.sp, method = 'bilinear', fun = mean, na.rm=TRUE))
village.sp$public <- as.numeric(raster::extract(public.img, village.sp, method = 'bilinear', fun = mean, na.rm=TR
UE))
village.sp$recreation <- as.numeric(raster::extract(recreation.img, village.sp, method = 'bilinear', fun = mean,
na.rm=TRUE))

village.sp$worship <- as.numeric(raster::extract(worship.img, village.sp, method = 'bilinear', fun = mean, na.rm=
TRUE))
village.sp$industrial <- as.numeric(raster::extract(industrial.img, village.sp, method = 'bilinear', fun = mean,
na.rm=TRUE))
village.sp$aquaculture <- as.numeric(raster::extract(aquaculture.img, village.sp, method = 'bilinear', fun = mean
, na.rm=TRUE))
```

2.3 Access to natural resources

```
village.sp$SCrainfed1 <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==1), village.sp, method = 'bilinear'
, fun = sum))
village.sp$SCrainfed2 <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==2), village.sp, method = 'bilinear'
, fun = sum))
village.sp$SCrainfed3 <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==3), village.sp, method = 'bilinear'
, fun = sum))
village.sp$SCirrigated <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==4), village.sp, method = 'bilinea
r', fun = sum))
```

```
village.sp$DCirrigated <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==5), village.sp, method = 'bilinea
r', fun = sum))
village.sp$TCirrigated <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==6), village.sp, method = 'bilinea
r', fun = sum))
village.sp$SCmixed <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==7), village.sp, method = 'bilinear', f
un = sum))
village.sp$shrubagri <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==8), village.sp, method = 'bilinear',
 fun = sum))
village.sp$forest <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==9), village.sp, method = 'bilinear', fu
n = sum))
village.sp$urban <- as.numeric(raster::extract(area(lulc.img)*(lulc.img==10), village.sp, method = 'bilinear', fu
n = sum))
```

3 Save results

Save the workspace image.

```
rm(list=setdiff(ls(), "village.sp"))
save.image(file='data/ambio.RData')
```

Socio-Ecological System Profiling of Rural Communities - Cluster Analysis

Tristan Berchoux

November 2017

- 1 Loading data
- 2 Preparing the variables
- 3 Cluster analysis
- 4 Discussion

1 Loading data

Let's load all the required packages. Make sure they're loaded in this order.

```
library(raster)
library(sf)
library(tidyverse)
library(cowplot)
library(spocc)
library(rgdal)
```

```
## Warning: package 'rgdal' was built under R version 3.4.3
```

```
library(fpc)
library(maptools)
library(mapview)
library(osmar)
library(osmdata)
```

We are now going to load the data that we already pre-processed and we will also set the working directory.

```
setwd("/Users/tb2g14/Dropbox/soton/projects/p2_ambio/")
village.sf <- st_read("outputs/villageOUT.shp")
```

```
## Reading layer `villageOUT' from data source `/Users/tb2g14/Dropbox/soton/projects/p2_ambio/outputs/villageOUT.
shp' using driver `ESRI Shapefile'
## Simple feature collection with 6859 features and 429 fields
## geometry type:  POLYGON
## dimension:      XY
## bbox:           xmin: 84.97032 ymin: 19.46461 xmax: 86.99057 ymax: 21.23928
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```
village.sp <- as(village.sf, 'Spatial')
```

2 Preparing the variables

```
census.sp <- village.sp[!is.na(village.sp$markt),]
census.sp$area <- raster::area(census.sp)
mydata <- census.sp@data[,408:430]
```

Distance

```
mydata[, 1:12][mydata[, 1:12] == 0] <- 1
mydata[,1:12] <- 1/mydata[,1:12]
```

Area

```
mydata[,13:22] <- (mydata[,13:22]/census.sp@data[,36])
```

```
mydata <- data.frame(scale(mydata[,1:22]))
```

3 Cluster analysis

We are going to use four packages to compute different types of cluster analysis.

```
library(mclust)
```

```
## Warning: package 'mclust' was built under R version 3.4.3
```

```
#library(pvclust)
#library(dbscan)
```

```
fit <- Mclust(mydata) ; summary(fit)
```

```
## ----------------------------------------------------
## Gaussian finite mixture model fitted by EM algorithm
## ----------------------------------------------------
##
## Mclust VEV (ellipsoidal, equal shape) model with 4 components:
##
##  log.likelihood    n   df      BIC      ICL
##        326511.8 6853 1040 643837.9 643761.8
##
## Clustering table:
##    1    2    3    4
## 2571 3345  805  132
```

```
mydata$CLUSTER <- fit$classification

census.sp$CLUSTER <- fit$classification
save(census.sp,file='cluster.RData')
#amenities.df <- mydata[,1:12]
#lulc.df <- mydata[,13:22]
```

We are gonna set a new function called `multiplot()` that will enable us to plot different figures on a same plot when using `ggplot`.

```
multiplot <- function(..., plotlist=NULL, file, cols=1, layout=NULL) {
  library(grid)

  # Make a list from the ... arguments and plotlist
  plots <- c(list(...), plotlist)

  numPlots = length(plots)

  # If layout is NULL, then use 'cols' to determine layout
  if (is.null(layout)) {
    # Make the panel
    # ncol: Number of columns of plots
    # nrow: Number of rows needed, calculated from # of cols
    layout <- matrix(seq(1, cols * ceiling(numPlots/cols)),
                     ncol = cols, nrow = ceiling(numPlots/cols))
  }

  if (numPlots==1) {
    print(plots[[1]])

  } else {
    # Set up the page
    grid.newpage()
    pushViewport(viewport(layout = grid.layout(nrow(layout), ncol(layout))))

    # Make each plot, in the correct location
    for (i in 1:numPlots) {
      # Get the i,j matrix positions of the regions that contain this subplot
      matchidx <- as.data.frame(which(layout == i, arr.ind = TRUE))

      print(plots[[i]], vp = viewport(layout.pos.row = matchidx$row,
                                      layout.pos.col = matchidx$col))
    }
  }
}
```

After defining a color palette for each variable by using the `RColorBrewer` package, we are running a loop to plot the mean value of the different variables for each cluster.

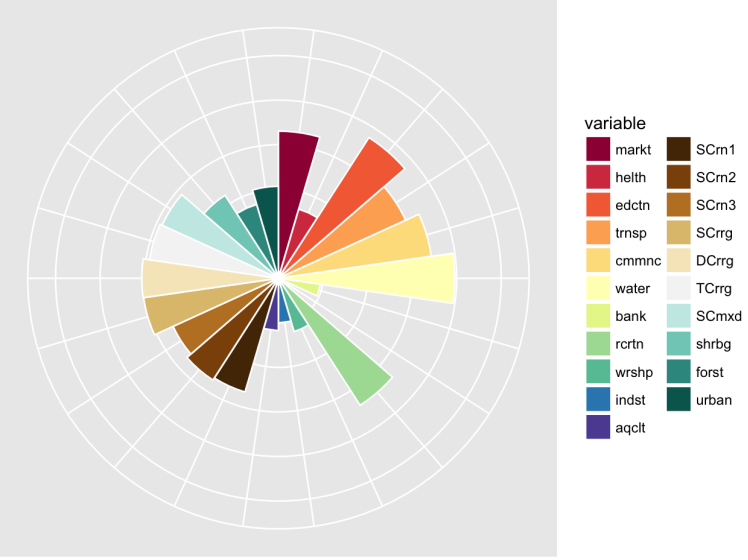
```
library(RColorBrewer)
cols <- c(brewer.pal(11, "Spectral"), brewer.pal(11, "BrBG"))


for (i in 1:fit$G){
  DF <- as.data.frame(colMeans(mydata[mydata$CLUSTER == i, 1:length(mydata[1,])-1]))
  DF <- data.frame(rownames(DF), DF[,1]) ; DF[,2] <- DF[,2] + 1 ; DF
  names(DF) <- c('variable','value')
  DF$variable <- factor(DF$variable, as.character(DF$variable))

  plot <- ggplot(DF, aes(variable, value, fill = variable)) +
    geom_bar(width = 1, stat = "identity", color = "white") +
    ylim(0,5) +
    #scale_y_discrete(breaks = 0:nlevels(DF$variable)) +
    scale_fill_manual(values=cols) +
    theme_gray() +
    theme(axis.ticks = element_blank(),
      axis.text = element_blank(),
      axis.title = element_blank(),
      axis.line = element_blank())

  nam <- paste('p',i, sep='')
  assign(nam, plot + coord_polar())
}

p1 ; p2 ; p3 ; p4
```



Socio-Ecological System Profiling of Rural Communities - Logistic Regression

Tristan Berchoux

December 2017

- 1 Loading data
  - 1.1 Loading packages
  - 1.2 Loading data
  - 1.3 Preparing the data
- 2 Logistic regression
  - 2.1 Cluster 1
  - 2.2 Cluster 2
  - 2.3 Cluster 3
  - 2.4 Cluster 4
- 3 Discussion

1 Loading data

```
setwd("/Users/tb2g14/Dropbox/soton/projects/p2_ambio/")
```

1.1 Loading packages

Let's load all the required packages. Make sure they're loaded in this order.

```
library(raster)
library(sf)
library(tidyverse)
library(cowplot)
```

```
library(spocc)
library(rgdal)
```

```
## Warning: package 'rgdal' was built under R version 3.4.3
```

```
library(fpc)
library(maptools)
library(mapview)
library(osmar)
library(osmdata)
```

1.2 Loading data

We are now going to load the data that we already pre-processed and we will also set the working directory.

```
census.sf <- st_read("outputs/cluster_V2.shp")
```

```
## Reading layer `cluster_V2' from data source `/Users/tb2g14/Dropbox/soton/projects/p2_ambio/outputs/cluster_V2.
shp' using driver `ESRI Shapefile'
## Simple feature collection with 6853 features and 431 fields
## geometry type:  POLYGON
## dimension:      XY
## bbox:           xmin: 84.97032 ymin: 19.46461 xmax: 86.97855 ymax: 21.23928
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```
census.sp <- as(census.sf, 'Spatial')
census.df <- data.frame(read_csv('data/tbl_census/census.csv'))
```

```
names(census.sp)[3] <- 'ADMIN_VILL_CODE'
census.sp@data <- inner_join(census.sp@data, census.df,by = "ADMIN_VILL_CODE")
mydata <- census.sp@data
```

1.3 Preparing the data

```
mydata$NATURAL_HH_RANK5_V2 <- factor(mydata$NATURAL_HH_RANK5_V2)
mydata$PHYSICAL_HH_RANK5_V2 <- factor(mydata$PHYSICAL_HH_RANK5_V2)
mydata$HUMAN_HH_RANK5_V2 <- factor(mydata$HUMAN_HH_RANK5_V2)
mydata$FINANCIAL_HH_RANK5_V2 <- factor(mydata$FINANCIAL_HH_RANK5_V2)
mydata$SOCIAL_HH_RANK5_V2 <- factor(mydata$SOCIAL_HH_RANK5_V2)
```

2 Logistic regression

```
library(R2MLwiN)
options(MLwiN_path = '/Users/tb2g14/Documents/mlwin/mlnscript')
```

2.1 Cluster 1

```
(model1 <- runMLwiN(logit(LIV_UNEMPL, DENOM2) ~ 1 + SOC_POPDENSITY + ADMIN_DISTRICT_NAME + NATURAL_HH_RANK5_V2 +
 PHYSICAL_HH_RANK5_V2 + HUMAN_HH_RANK5_V2 + FINANCIAL_HH_RANK5_V2 + SOCIAL_HH_RANK5_V2 + (1 | ADMIN_GRAM_NAME), D
 = "Binomial", data = mydata[mydata$CLUSTER==1,]))
```

```
(model2 <- runMLwiN(logit(LIV_UNEMPL, DENOM2) ~ 1 + SOC_POPDENSITY + ADMIN_DISTRICT_NAME + NATURAL_HH_RANK5_V2 +
 PHYSICAL_HH_RANK5_V2 + HUMAN_HH_RANK5_V2 + FINANCIAL_HH_RANK5_V2 + SOCIAL_HH_RANK5_V2 + (1 | ADMIN_GRAM_NAME), D
 = "Binomial", estoptions = list(nonlinear = c(N = 1, M = 2), startval = list(FP.b = model1@FP, FP.v = model1@FP.
cov, RP.b = model1@RP, RP.v = model1@RP.cov)), data = mydata[mydata$CLUSTER==1,]))
```

```
##
## -*-*-*-
```

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