Livelihoods, poverty and targeting

in the Indo-Gangetic Plains:

a spatial mapping approach

Olaf Erenstein, Jon Hellin & Parvesh Chandna

Rice Wheat
CIMMYT

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Olaf Erenstein[1], Jon Hellin[2] & Parvesh Chandna[1]

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[1] CIMMYT India and Rice-Wheat Consortium for the Indo-Gangetic Plains, CG Block, NASC Complex, DPS Marg, Pusa Campus, New Delhi-110012, INDIA

[2] CIMMYT, Apdo Postal 6-641, 06600 Mexico D.F., Mexico

[3] The study benefited from financial support from USAID India. The views expressed in this report are those of individual scientists and do not necessarily reflect the views of their institution or the donor. Corresponding author: o.erenstein@cgiar.org.

CIMMYT® (www.cimmyt.org) is an internationally funded, not-for-profit organization that conducts research and training related to maize and wheat throughout the developing world. Drawing on strong science and effective partnerships, CIMMYT works to create, share, and use knowledge and technology to increase food security, improve the productivity and profitability of farming systems, and sustain natural resources. Financial support for CIMMYT's work comes from many sources, including the members of the Consultative Group on International Agricultural Research (CGIAR) (www.cgiar.org), national governments, foundations, development banks, and other public and private agencies.

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Abstract: This study develops a spatial mapping methodology as a tool to guide priority-setting and targeting of poverty-alleviation activities. It applies this tool to the Indo-Gangetic Plains of South Asia, the target domain of the Rice-Wheat Consortium (RWC). It draws on secondary data for 18 quantitative, spatially-explicit variables at the district level, which serve as indicators of poverty levels based on the five livelihood capitals of the sustainable livelihoods approach: natural, social, human, physical, and financial. The study details the methodology used and generates spatial poverty maps for composite indicators for each of the five categories of livelihood assets, as well as an overall livelihood asset index. The overall livelihood asset index showed a significant and strong negative correlation (R = -0.65) with the more conventional monetary method for assessing poverty. Research and development implications are then explored.

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List of acronyms

BPL	below the poverty line
CIMMYT	International Maize and Wheat Improvement Centre (www.cimmyt.org)
ICAR	Indian Council for Agricultural Research (www.icar.org.in)
IGP	Indo-Gangetic Plains
LGP	Lower-Gangetic Plain (Part of the IGP, in this study comprising the downstream plains in eastern India [West Bengal], Ganges basin)
MDG	Millennium Development Goal
MGP	Middle-Gangetic Plain (Part of the IGP, in this study comprising the midstream plains in eastern India [Eastern UP, Bihar], Ganges basin)
n	number of observations
NGO	non-governmental organization
p.a.	per annum (per year)
p.	One-way significance of difference amongst means
RWC	Rice-wheat consortium of the Indo-Gangetic plains (www.rwc.cgiar.org)
std.dev.	standard deviation
TGP	Trans-Gangetic Plain (Part of the IGP, in this study comprising the plains in northwestern India [Punjab, Haryana], straddling Ganges and Indus basin)
UGP	Upper-Gangetic Plain (Part of the IGP, comprising the upstream plains in north-central India [western UP], Ganges basin)
UP	Uttar Pradesh

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Executive summary

The target of the first Millennium Development Goal (MDG) is to halve hunger and poverty by 2015 from 1990 levels. The focus on poverty reduction has led to an increased interest on the part of policy makers, researchers, and development practitioners in priority-setting and targeting so as to ensure maximum impact on poverty reduction and improved livelihood security. As a consequence, there is a focus on documenting the geographic dimensions of poverty and food security, particularly through the use of spatial poverty maps.

The Rice-Wheat Consortium for the Indo-Gangetic Plains (RWC) faces the challenge of identifying areas where it should focus its activities in order to contribute most to alleviating poverty. This is not a straightforward task, partly because of differences in how poverty should be measured (e.g. using a monetary versus capability approach), but also because of uncertainty about the likely poverty reduction impact of the RWC's activities.

This study develops a spatial mapping methodology for the Indo-Gangetic Plains (IGP) that can serve as a tool to guide priority-setting and targeting within the RWC. The approach specifically incorporates livelihood and poverty considerations. The study draws on secondary data and uses 18 quantitative, spatially-explicit variables, which serve as indicators of poverty levels based on the five livelihood capitals of the sustainable livelihoods approach: natural, social, human, physical, and financial. The livelihood assets approach to measuring poverty complements the more conventional monetary approach.

The study details the methodology used to generate spatial poverty maps at the district level for composite indicators for each of the five categories of livelihood assets, as well as an overall livelihood asset index. Each individual asset index shows statistically significant variation between the four sub-regions of the IGP, which cover the states of Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal. The overall livelihood asset index showed a significant and strong negative correlation (R = -0.65) with the more conventional monetary method for assessing poverty.

It is the decisions of millions farmers throughout the IGP that ultimately will determine whether the resource-conserving technologies promoted by the RWC are adopted and adapted, impacts registered, poverty reduced, and livelihoods improved. The approach outlined in this report provides a tool for priority-setting and targeting, but does not set priorities as such. This research report needs to be complemented by a better comprehension of previous development and research experiences in order to shed more light on farmers' livelihoods in the IGP and the impact pathways and networks that link research outputs (technology and information) to farm household-level impact. Having mapped the livelihood assets, we now need to better understand the asset-poverty linkages and the trade-offs between alternative investments so as to enhance R&D priority-setting in the IGP.

1 Introduction

Poverty alleviation has been a persistent goal of development for five decades. The target of the first Millennium Development Goal (MDG) is to halve hunger and poverty by 2015 from 1990 levels. The special Hunger Task Force of the United Nations Millennium Project, established to promote immediate action towards achieving this goal, is emphasizing the need to renew and increase support for smallholder farming (Food and Agriculture Organization, 2004:25). Similarly, the World Bank sees broad-based agricultural growth in low-income countries as essential to reach the first MDG (World Bank, 2005a; World Bank and IFPRI, 2006). Indeed, despite the huge gains in agricultural productivity over the last five decades and despite rapid urbanization, an estimated 70-75% of the world's poorest people live in rural areas, where their livelihoods are largely dependent on agriculture.

India has demonstrated that agricultural development provides an effective means for both reducing poverty and accelerating economic growth (Food and Agriculture Organization, 2004:4). When India gained independence in 1947, more than 60% of the population was living below the poverty line (Jayaraman and Srivastava, 2003). Despite rapid population growth from 350 million to over 1 billion, the share of the population living on less than "a dollar a day"[4] declined significantly over time, from 54% in 1981 to 42% in 1990 and 35% in 2001 (Chen and Ravallion, 2004:30). The steady decline in poverty from the mid-1960s to the early 1980s was strongly associated with agricultural growth, particularly the Green Revolution (Jayaraman and Srivastava, 2003). However, despite huge advances, rural poverty remains endemic in many parts of India and half of India's under-five-year-olds are underweight. Although agriculture contributes only about one-quarter of India's total gross domestic product (GDP), its importance in the economic, social, and political fabric is far greater than this contribution would suggest. Therefore fostering rapid and sustained agricultural and rural growth and development remains a key priority of the Government of India.

The incidence of poverty in India, however, has intra-regional patterns, raising the question of where research and development efforts should be focused in order to have the maximum impact on poverty reduction. While overall agricultural growth is an effective means for economic development and poverty reduction, the form that this growth takes has a bearing on its effectiveness in reducing rural poverty. For instance, increased productivity on smallholders' farms[5] is likely to have a broader impact on poverty reduction than productivity increases on large-scale mechanized farms (Dixon et al., 2001:7)[6]. In India, there is a high concentration of rural poor in low agricultural potential areas compared to high potential areas (e.g. rainfed vs irrigated, Fan and Hazell, 1997). Furthermore, there are data to suggest that poverty declined more in low potential areas between 1972 and 1987 than it did in high potential areas (Fan et al., 2000)[7]. This has important implications for where investments should be targeted in order to achieve further productivity growth and poverty alleviation (Jayaraman and Srivastava, 2003; Bigman and Fofack, 2000).

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[4] Actually US$1.08, taking into account the 1993 purchasing power parity (Kakwani, 2004:10).

[5] Based on Narayanan and Gulati (2002:5), we characterize smallholders as farmers (crop or livestock) who practice a mix of commercial and/or subsistence production, where the family provides the majority of labor and the farm provides the principal source of income.

[6] It is generally expected, however, that in the future a smaller proportion of the population will be involved in farming and that larger numbers of people will be employed in other parts of the rural and urban economy (Tripp, 2001).

[7] The greater reduction in low potential versus high potential areas has, however, been disputed: see, for example, Palmer-Jones (2003).

India has considerable experience of priority-setting and targeting within the agriculture sector. The National Centre for Agricultural Economics and Policy Research (NCAP) has played a key role in supporting country-wide priority-setting by the Indian Council of Agricultural Research (ICAR). Mirroring a worldwide trend (Hyman et al., 2005; Amarasinghe et al., 2005; Bellon et al., 2005; Kam et al., 2005), a common feature of many priority-setting and targeting initiatives in India has been the use of spatial poverty maps, particularly at the state level (e.g. M.S. Swaminathan Research Foundation, 2004; Planning Commission, 2002). The maps are used to inform policy makers, researchers, and development practitioners of specific areas where there may be a concentration of poverty and where development efforts may best be directed (Palmer-Jones and Sen, 2006). While poverty maps have been variously used for planning and management in India, their definition is often "*contextual depicting more the attributes/indicators of poverty rather than the spatial representation of income poverty per se*" (Jayaraman and Srivastava, 2003: 3).

For poverty mapping to be a useful poverty alleviation tool, there is a need to seek out the most disaggregated data available. Large scale poverty maps are unable to capture the heterogeneity that exists; consequently poor people may not be included in poverty-reduction programs. A very simple example is that if only low potential areas are targeted then poor farmers in high potential areas are ignored. Similarly, the blanket targeting of low-potential areas may still lead to the benefits of any program being captured by wealthy farmers in these areas. Bigman and Srinivasan (2003) discuss some of the challenges and pitfalls of spatial poverty mapping in India. The authors argue that targeting at the district as opposed to state level is likely to lead to less "*leakage to the non-poor*" because the size of the population in each target area is reduced from 40 to two million.

Some studies have generated spatial poverty maps in India based on district-level data. Bansil (2006) used poverty maps in Rajasthan, grouping a range of development indicators into nine categories (demography, housing and sanitation, literacy, health, nutrition, agriculture, livestock, infrastructure, and development) and weighting these categories to generate a composite human poverty index. Debroy and Bhandari (2003) also generated poverty maps for India based on a range of poverty indicators including living standards (head count ratio, i.e. % of population below the national poverty line), health (infant mortality rate), education (literacy rate), and gender equality (ratio of female to male literacy rate). Spatial mapping of district-level data is not limited to poverty mapping per se. Yadav and Subba Rao (2001) have mapped cropping systems at the district level, while Kumar et al. (2002) mapped productivity indicators at the district level for the Indo-Gangetic Plains (IGP).

During the decades following the Green Revolution, improved cereal germplasm made a major contribution to food security through increased food production and reduced food prices for the urban and rural poor. The majority of the additional food was produced in irrigated, high-potential areas in the IGP, particularly in the states of Punjab and Haryana, often by farmers with reasonable access to resources and markets. There were also some indirect benefits in the form of spillovers as germplasm targeted to irrigated areas was adopted by farmers in medium-potential areas. Despite a slowdown in productivity growth (e.g. Kumar et al., 2002), the IGP continue to contribute significantly to agricultural production in India, especially of rice and wheat. However, the IGP cover a vast area, with significant diversity in terms of agricultural potential, incidence of poverty, the realized impact of the Green Revolution and environmental problems. Confronted with such diversity, Research and Development (R&D) organizations such as the Rice Wheat Consortium for the Indo-Gangetic Plains (RWC) have to make decisions as to where to work within the IGP and which groups to target (RWC, 2006).

The RWC was formed in 1994 to address concerns about the sustainability of the rice-wheat systems of the IGP. It encompasses the national agricultural research systems (NARSs) in Bangladesh, India, Nepal, and Pakistan, and international centers including the International Maize and Wheat Improvement Center (CIMMYT), the International Rice Research Institute (IRRI), and others (see http://www.rwc.cgiar.org). The consortium provides a platform for commodity-based research institutions to engage in collaborative, integrated systems research to address natural resource management and agricultural productivity issues and develop technologies that enhance the productivity and sustainability of rice-wheat systems in the IGP. A review of the RWC concluded that the consortium "*needed to be more explicit in its response to the revised assistance strategies of donors funding research to have greater impact on poverty alleviation, sustainability and the environment*" (Seth et al., 2003: xi). The RWC, therefore, needs to target its activities to those areas within the IGP where it would contribute most to alleviating poverty. Given the agro-ecological and socio-economic diversity within the IGP and the paucity of disaggregated data, this is not as simple as it might seem.

The objective of this study was to develop a spatial mapping methodology for the IGP so as to incorporate livelihood and poverty considerations into R&D priority-setting and targeting. The study draws on secondary data and illustrates the methodology through spatial poverty maps at a district level for the various livelihood assets, and discusses the implications. It is, therefore, of use to policy makers, researchers, or development practitioners who are involved in efforts to ensure that the agricultural sector continues to contribute to poverty reduction and economic growth in India in general and the IGP in particular.

In the next chapter we outline the different ways to assess poverty and explain why we eschew a narrow definition of poverty in favor of a broader definition based on the five assets of the livelihoods approach (natural, social, financial, human, and physical capital). The chapter includes a description of the livelihoods approach. In Chapter 3, we provide details on the methodology used in the study: the secondary data sources used, the selection of livelihood variables, the handling and spatial mapping of these variables, and the generation of composite poverty variables based on the five livelihood assets. In Chapter 4, we present the results in a series of maps and tables that show the regional variation at district level for each of the livelihood assets across the IGP. These results are discussed in Chapter 5, and we outline some of the challenges in making even more practical use of the spatial maps in terms of linking them to farmers' livelihood systems. In Chapter 6, we draw conclusions from the study.

2 Conceptual framework

2.1 Poverty definition

While there is worldwide agreement on poverty reduction as an overriding goal of development policy, there is actually little agreement on the definition of poverty. The poverty line of average daily consumption equivalent to US$1 per day per capita is not the only indicator for determining poverty. It is argued that the conventional reductionist and standardized views of poverty differ from those of the poor themselves: a focus on income-poverty may reflect Northern concerns on the South, whilst poor people's definitions of poverty may differ from those assumed for them by professionals (Chambers, 1995; Chambers, 1997b). It is questioned whether the definition of poverty should be confined to material aspects of life, or include social, cultural, and political aspects (Bansil, 2006:xv). There is, therefore, a strong justification for alternative definitions of poverty. Clarity as to how poverty is defined is extremely important as different definitions imply the use of different indicators. This in turn may lead to the identification of different individuals and groups as poor and require different policy solutions for poverty reduction. Following Ruggeri Laderchi et al (2003) we outline four approaches to the definition and measurement of poverty: the monetary approach; social exclusion; participatory approaches; and capability.

The **monetary approach** to the identification and measurement of poverty is the most commonly used. It identifies poverty with a shortfall in consumption (or income) from some poverty line, e.g. US$1 per day per capita. The valuation of the different components of income or consumption is done at market prices. This requires identification of the relevant market and the attribution of monetary values to those items that are not valued through the market, such as subsistence production (Ruggeri Laderchi et al., 2003). The monetary approach is often favored because country-level data are normally available at regular intervals. In addition, the data are usually available on a continuum so it is possible to vary the poverty line, and to measure the depth of poverty.

The concept of **social exclusion** was developed in industrialized countries to describe the processes of marginalization and deprivation that can arise within rich countries. Social exclusion is often a characteristic pertaining to groups—the aged, handicapped, racial, or ethnic categories—rather than individuals.

In recent years a strong case has also been made that knowledge about poverty should focus on the understandings of poor people and the concepts that they use (Chambers, 1997a). The **participatory approach** is unique because rather than outsiders deciding on poverty levels, it aims to encourage people themselves to participate in decisions about what it means to be poor, and the magnitude of poverty. The emphasis is on poor people’s ability to understand and analyze their own reality.

The **capability approach** rejects monetary income as its measure of well-being and recognizes poverty as a multidimensional phenomenon rather than just a lack of income or food. As Kapur Mehta and Shah (2002) have noted for India, poverty is the sum total of a multiplicity of factors that include not just income and calorie intake but also access to land and credit, nutrition, health and longevity, literacy and education, and safe drinking water, sanitation and other infrastructural facilities. The capability approach focuses on indicators of the freedom to live a valued life and, therefore, suggests a new way to think about productivity rather than just in terms of yield (kg/ha) or salary ($/hour of work). Poverty can be defined as the failure to achieve certain minimal or basic capabilities, where ‘basic capabilities’ are the ability to satisfy certain crucially important functions up to certain minimally adequate levels (Sen, 1993: 41). In this sense, the capability approach complements the sustainable livelihoods approach adopted by many research and development organizations and one that we chose to follow in this study.

2.2 Sustainable livelihoods

Livelihoods approaches in general and the Sustainable Livelihoods Approach (SLA) in particular tend not to have a precise definition, but rather can be described as “*a way of thinking about the objectives, scope and priorities for development in order to enhance progress in poverty elimination*” (Ashley and Carney, 1999: 1). The SLA is a way of looking at development in a way that is concerned principally with people. The approach seeks to understand people's strengths, including their skills and possessions, and how they use these assets to improve the quality of their lives. Chambers and Conway (1991) have defined a livelihood as comprising the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is thereby sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.

The SLA has been widely used in development work for well over a decade, including agriculture, forestry and fisheries (Allison and Horemans, 2006; Bebbington, 1999; Bird and Shepherd, 2003; Bond and Mukherjee, 2002). The SLA is comprised of a **development objective** which is to support the goal of poverty reduction and elimination, and an **analytical framework** that provides a means of understanding the factors that influence the ability of people to achieve sustainable livelihoods in particular circumstances. The third component, at the heart of the SLA, is a set of **principles** for poverty-focused development, namely:

- **People-centered**: focusing on what matters to people.
- **Holistic**: identifying constraints and opportunities regardless of the sector, geographical space, or level at which they occur.
- **Responsive and participatory**: poor people themselves must be the key actors.
- **Multi-level**: working at all levels and building on the linkages between them.
- **Conducted in partnership**: with both the public and the private sector.
- **Sustainable**: economically, institutionally, socially, and environmentally.
- **Dynamic**: recognizing the dynamic nature of livelihood strategies and responding flexibly.

Figure 1 illustrates the five key elements of the **analytical framework** of the SLA: a) vulnerability context, b) livelihood assets, c) policies, institutions, and processes, d) livelihood strategies, and e) livelihood outcomes.

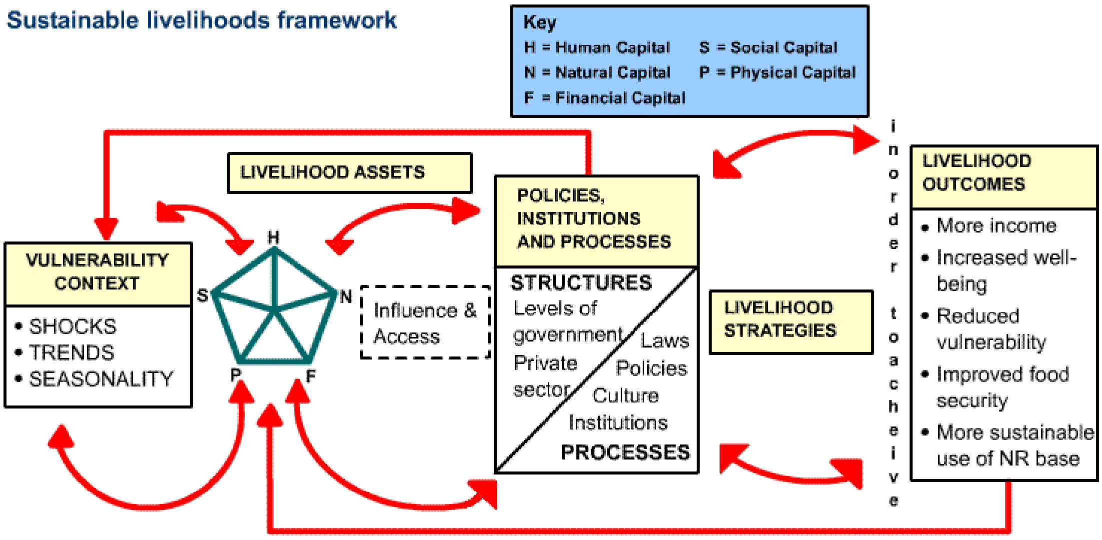

Figure 1 Sustainable livelihoods framework.
Source: DFID (2003)

The starting point is the **vulnerability context** within which people, including farmers, operate. The vulnerability context can be understood as the “external” influences on livelihoods that impact on peoples’ asset base, comprising shocks, trends, and seasonality. Shocks include changes in political systems, devaluation, outbreaks of new diseases, war, floods, and droughts. Trends (usually perceived as negative) include environmental degradation, population increase, moral decline, falling educational and health-care standards, inflation, rising unemployment, declining farm sizes, and increasing pest and disease levels. Seasonality influences include the effects of weather patterns on agricultural production, livestock nutrition and diseases, access to markets and health etc.

Next, the major building blocks are people’s **livelihood assets**, the focus of this report. The SLA identifies five classes of assets: human, social, natural, physical, and financial capital upon which people draw for their livelihoods (DFID, 2003). In this context, capital does not mean capital stocks in the strict economic sense of the term.

- **Natural capital** is the term used for the natural resource stocks such as vegetation, land, water, and air.
- **Social capital** reflects the patterns and systems of social organizations that facilitate or constrain co-operative enterprise and inter-household relations e.g. community-based organizations and religious groups.
- **Human capital** includes the levels of education, knowledge, and health that enable people to experiment, solve their own problems, and pursue different livelihood strategies.
- **Physical capital** comprises the basic infrastructure needed to support livelihoods and includes: affordable transport; secure shelter and buildings; and adequate water supply.
- **Financial capital** is the financial resources that people use to achieve their livelihood objectives and includes access to credit, loans, savings, and remittances.

The five types of assets can be seen as livelihood building blocks and are represented by the pentagon in figure 1. Sustainable livelihood development and poverty reduction depends not on advances in access to just one of the classes of assets but on systematic approaches to achieve an appropriate balance between these essential assets. Poor people can, therefore, be conceptualized as those that have few or low-productivity assets. Subsequently, it is difficult for them to accumulate or enhance their assets and hence to improve their livelihood outcomes. This traps them in a circle of poverty.

In India, a distinct category of the poor is the chronic poor. Based on a capability approach, chronic poverty can be viewed as occurring when an individual experiences significant capability deprivations for a period of five years or more. The distinguishing feature of chronic poverty is its extended duration. Intuitively, we are talking about people who remain poor for much of their life and who may ‘pass on’ their poverty to subsequent generations (Hulme and Shepherd, 2003). The chronic poor are often found in areas beset by low endowments of all five capital assets. They are often those discriminated against because of their social position at the local, regional, or national level, e.g. marginalized castes, ethnic, racial, or religious groups; refugees; indigenous people; nomads and pastoralists; and migrants. In India, two thirds of the bonded laborers identified (essentially chronically poor with likelihood of intergenerational transmission of poverty) are from scheduled castes and scheduled tribes (as defined by the Constitution of India and attached schedules, Saxena and Farrington, 2003).

In the context of the SLA, interventions to fight poverty, such as the provision of education, health services, better transportation, better agricultural technologies, micro-credit, or even cash transfers, can be seen as ways of enhancing the productivity of the five assets. Better education and health services enhance human capital. Resource-conserving technologies enhance the productivity of natural capital. Getting farmers organized into groups to purchase inputs or test new technologies enhances their social capital. Better roads and transportation enhances their physical capital. Finally, credit and cash transfers can improve farmers’ financial capital.

The livelihoods approach was considered particularly appropriate for the IGP because the response to shocks and the ability to cope with vulnerability are very much dependent on assets. Livelihoods analysis, therefore, has particular relevance for understanding this definition of poverty, as it permits the tracking over time of a household’s assets (human, social, natural, physical, and financial) in relation to its vulnerability context and, as we will see below, the institutions, organizations, and policies that mediate its external economic and social relationships (Ellis, 2000). A particular strength of this approach is that it recognizes human agency and examines the way in which household livelihood strategies are built around protecting, substituting, increasing, and using assets to produce security and achieve other goals (Hulme and Shepherd, 2003).

Although the individual, farm household, and community are the primary level of analysis, livelihood approaches also address relevant interactions at micro-, meso-, and macro-levels through interactions with the remaining three elements of the SLA framework. Assets interact with **policies, institutions, and processes** to shape the choice of livelihood strategies that farmers follow in pursuit of livelihood outcomes such as more income, increased food security, and more sustainable use of natural resources. Policies, institutions, and processes that shape livelihoods may include the performance of agricultural extension services, credit, agricultural inputs, and markets for produce. They could also include policies such as agricultural liberalization. Institutions may also refer to local community structures, norms, and power relations that regulate access to resources.

The **livelihood strategies** refer to the combination of activities that households engage in for their living. One of the important characteristics of the SLA is that it recognizes that farmers may well pursue multiple strategies sequentially or simultaneously in pursuit of their preferred livelihood outcomes. Rural livelihoods, therefore, tend to be diverse and complex, with farmers reliant on non-agricultural and non-farm as well as agricultural and farm sources (Rigg, 2006).

The SL framework does not place livelihood strategies within an explicit normative behavioral framework. However, an underlying assumption of rational (optimizing) behavior may be inferred: that people will adopt strategies to preserve and improve their asset base. The **livelihood outcomes** refer to those outcomes of strategies that improve the asset base of poor people. Examples might include improved productivity of land, livestock, or labor; better health; and a more regular cash income, better access to credit, or more investment options. Outcomes are related to the goals which individuals and households pursue.

The SLA combines an objective, a framework for analysis and a set of principles that together constitute an approach. Livelihoods approaches are often claimed to represent best practice in rural research and development. Whilst it has proved to be a useful tool, the SLA is not without its critics. Dorward et al. (2003) point out that an important gap in the conceptualization and application of the SLA and other livelihood approaches is the lack of emphasis on markets and their roles in livelihood development and poverty reduction. As such, there is a danger of failing to identify and act on livelihood opportunities and constraints arising from critical market processes, and institutional issues that are important for pro-poor market development. Others, such as Ellis (2000), have adapted the original SLA to make it more practical (Figure 2).

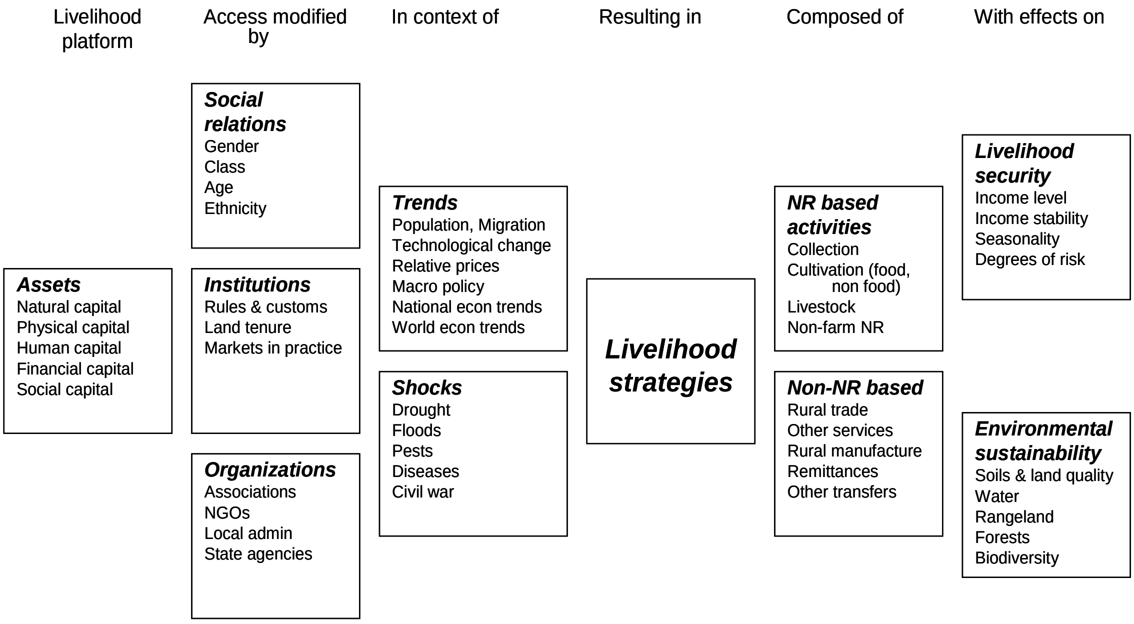

Figure 2 A framework for the analysis of rural livelihoods.
Source: Ellis (2000)

Use of the SLA in poverty-mapping also poses a number of challenges. Different types of data are often unavailable on a regular basis and may rely on one-off surveys. A major impediment to the development of poverty maps has been that needed data on income or consumption typically are available only from relatively small surveys. Where census data have the required sample size, they generally do not have the required information for the generation of spatial livelihood poverty maps (Hentschel et al., 2000). Furthermore, some assets are not measured at all, and for others the indicators are deficient. Despite these shortcomings, the livelihoods or capabilities approach represents a major contribution to poverty analysis because it provides a coherent framework for defining poverty in the context of people's lives and the freedoms they enjoy (Beck and Nesmith, 2001).

3 Methodology

3.1 Research process

In terms of research process, the present study had four main phases. The first phase primarily revolved around consultation with stakeholders, initial literature review, and methodology development for the spatial knowledge base. This included a stakeholder meeting held in New Delhi in August 2005 to discuss livelihood patterns, dynamics, and impact pathways in the IGP with representatives from a selection of Indian research and policy institutions. The meeting identified a list of indicators and related data sources for each of the five asset bases of the sustainable livelihoods framework. These included, for example, road infrastructure, access to credit, agricultural yields, literacy rates, caste, and strength of self-help groups. The methodology builds on and complements earlier work (Bansil, 2006; Bigman and Srinivasan, 2002; Debroy and Bhandari, 2003).

The second phase primarily revolved around data-gathering. The focus was on secondary datasets that met a number of criteria, including being available for the entire study area, being spatially explicit, being disaggregated to the district level, and being relevant to the five livelihood assets. The third phase revolved around data analysis. This included spatial mapping of data, data-handling and standardization, indexing, aggregating, and statistical analysis. The final phase focused on detailing the findings in the present report to facilitate sharing the results with stakeholders. In the remainder of the chapter we introduce the study area and discuss in more detail the data sources, data-handling, and data used in the spatial knowledge base.

3.2 Study area

The Indo-Gangetic Plains (IGP) in India primarily comprise five states: Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal[8]. With the exception of Delhi, Calcutta, and Chandigarh, the 160 districts in these states are predominantly rural.

The IGP can be divided broadly into eastern and western sub-regions. The eastern sub-region has problems of poor water control and flooding. Rainfed (summer/*kharif*) lowland rice is the traditional cereal staple and the mainstay of food security; only in recent decades have wheat and other cool-season crops been introduced on a large scale. By contrast, the western sub-region is mainly semi-arid and would be water scarce were it not for an excellent irrigation infrastructure of canals and groundwater tubewells. In this sub-region, winter (*rabi*) wheat has traditionally been, and continues to be, the mainstay of food security, but in recent decades there has been a major increase in the area of rice grown in the summer/kharif season (Erenstein et al., 2006).

Throughout India, livestock is emerging as an important sector. In 2001/02 livestock accounted for 25 percent of agricultural GDP, or 5.6 percent of national GDP. The sector employs approximately 11 million and, because most livestock in India is owned by small and marginal farmers and landless households in rural areas, the sector's rapid growth benefits the poorest households. Ruminant livestock—particularly buffalo, cattle, and goats—are an integral part of the farming systems of the IGP (Erenstein et al., 2006). In the eastern IGP cattle are the predominant livestock, whereas in the western IGP buffalo dominate. In broad terms, therefore, the eastern IGP are characterized by rural livelihoods based on rice-cattle farming systems, while rural livelihoods in the western IGP are based on wheat-buffalo farming systems.

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[8] There are three Indian districts that primarily fall within the IGP but outside of the five states considered here. These are Shri Ganganagar (Rajasthan) and Haridwar and Udam Singh Nagar (Uttaranchal).

In rural India, poverty is directly related to overall agricultural productivity, with poor agricultural output directly linked to the absence of irrigation facilities. The success of the Green Revolution, for example, was intimately linked to farmers having access to irrigation. Access to irrigation benefited farmers by enabling them to achieve higher productivity through the adoption of higher yielding varieties of crops, increased cropping intensity, and reduced vulnerability to weather risks; and in opening opportunities to cultivate higher value crops (World Bank, 2005b). This contributed to increased employment and incomes and the reduction of poverty in rural areas, and improved food security nationally. Lack of irrigation facilities is thus identified as one of the root causes of poverty, particularly for smallholders (Beck, 1995). It is no coincidence that one of the most heavily subsidized sectors in Indian agriculture is irrigation. In the states of Punjab and Haryana, developed irrigation is probably the most striking and widespread physical capital asset that farmers have (Erenstein et al., 2006).

There have been several attempts to classify India into agro-ecological zones which could characterize the ecological constraints on poverty alleviation. The Planning Commission divided the country into 15 broad agro-climatic zones based on physiography and climate. The State Agricultural Universities subsequently divided each zone/state into subzones under the National Agricultural Research Project (NARP), giving 127 sub-zones, primarily by rainfall, existing cropping pattern and administrative units (Velayutham et al., 1992:2). The Indian Council of Agricultural Research (ICAR) generated a national classification scheme, which divides India into 20 agro-ecological zones based on climatic conditions, length of growing period, landform, and soils (Velayutham et al., 1992).

Following the Planning Commission’s agro-climatic zones, the IGP in India is generally divided into four major sub-regions (Figure 3):

- Trans-Gangetic Plains (TGP): Punjab and Haryana in the northwestern plains.
- Upper Gangetic Plains (UGP): western and central Uttar Pradesh (UP).
- Mid-Gangetic Plains (MGP): eastern UP and Bihar.
- Lower Gangetic Plains (LGP): West Bengal.

The sub-regions group districts primarily on agro-ecological criteria (Kumar et al., 2002; Narang and Virmani, 2001). However, they also largely follow political state boundaries. As such, the sub-regions reflect a combination of agro-ecological, socio-economic and political factors and their interactions, rather than purely “agro-ecological zones”. A total of 11 out of 160 districts in the five states fall primarily outside the IGP and the corresponding sub-regions[9]. These districts are included in the analysis of state level data and the estimation of percentiles. However, they are excluded from the sub-region-specific estimates.

[9] These include 7 districts in UP: Jalaun (35), Jhansi (36), Lalitpur (37), Hamirpur (38), Mahoba (39), Banda (40), and Chitrakoot (41). They also include 4 districts in West Bengal: Darjiling (1), Jalpaiguri (2), Koch Bihar (3), and Puruliya (14). The numbers in parentheses are the district identification numbers as used in the population census and depicted in figure 3.

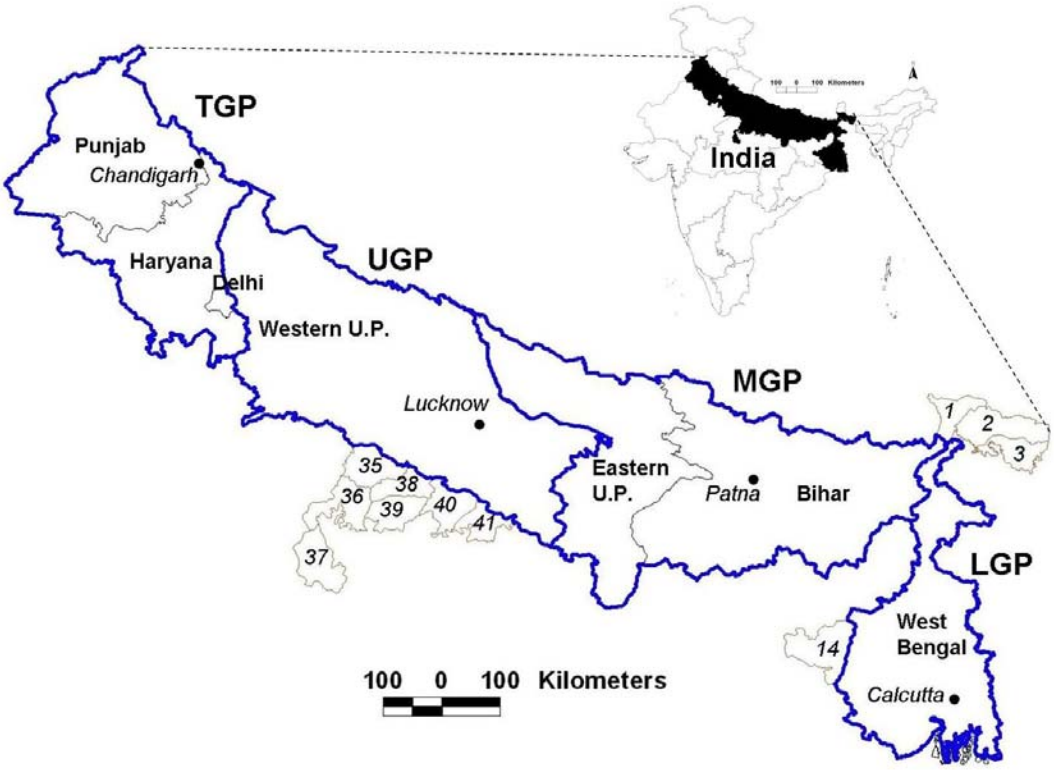


Figure 3 The sub-regions of the Indo-Gangetic Plains in India.

3.3 Data sources and issues

Poverty maps, spatial descriptions of the distribution of poverty, are most useful to policy makers and researchers when they are disaggregated, i.e. when they represent small geographic units, such as towns or villages (Alderman et al., 2002; Minot, 2000). For instance, the disaggregating of national averages provides a richer understanding of social disparities in health (Pande and Yazbeck, 2003). While some of these disaggregated data are available in India, they tend to be unavailable for most indicators. As a result, data sources were the principal constraint in operationalizing the livelihoods conceptual framework into a spatially explicit knowledge base.

To be of use, the secondary data sources had to meet a number of criteria. A first key criterion was the need to be available for all of the IGP study area. Some indicators are only available in selected localities (be it villages, districts, or states), limiting their use for cross-site comparisons. A second key criterion was the need to be spatially-explicit to allow for mapping and spatial analysis. A third key criterion was the need to be disaggregated to the lowest common scale across all data sources. Vast amounts of data are available at the state level. At lower aggregation levels, however, the number of available data sets that meet all criteria rapidly diminishes. A comparison across sources proved the district level to be the most relevant disaggregated level. The use of aggregated census data instead of household-level data to generate poverty estimates does lead, however, to some loss in precision (Minot and Baulch, 2005). The last key criterion was the need for the indicator to be relevant to any of the five livelihood assets.

The livelihood framework outlined in chapter 2 can be applied at different scales, although this raises certain issues, as the application of the livelihood approach at a higher aggregation level somewhat blurs the distinction between some assets and modifiers. For instance, a village level credit society would be considered a modifier at the household level but would be an asset at the village level. The livelihood approach is generally used at the household level. The number of studies applying the livelihood framework in the IGP is still extremely limited, resulting in only a marginal coverage. Furthermore, many studies are not directly comparable, for instance in terms of indicators covered or methodology followed. A separate companion study (Raina and Sulaiman, 2007) synthesizes available studies in the IGP. However, these sources generally did not meet all of the criteria for inclusion in the spatial knowledge base. The present study therefore limits itself primarily to the relevant available statistics.

There is no dearth of statistical data in India, e.g. see Bansil (2002) for a comprehensive overview. However, application of the aforementioned criteria quickly narrows down the relevant data sets. The present study has drawn primarily from the following secondary sources:

2001 Population Census and Village Directory

The first synchronous census in India was held in 1881. Since then, the census has been undertaken once every ten years. The Census of India 2001 is the sixth since independence. The results of the Census 2001 are available in various published and unpublished formats; two sources were of particular use in the context of the present study. CensusInfo 2001 (CensusIndia, 2005) is a CD that serves as a standalone spatial knowledge base with data on demography, occupation, and education. The Village Directory is an unpublished dataset that compiles village-level characteristics by state.

National Sample Survey Organization (NSSO)

The Government of India started the National Sample Survey (NSS) in 1950 to collect socio-economic data. It is a household survey that is carried out every year. Different subjects are surveyed in different rounds of the NSS, and every five years a large survey is carried out with the specific aim of recording household consumption in order to estimate poverty. Six of these large-sample consumer surveys have been conducted by the NSSO since 1973/74. The last consumer survey (the 55th round of the NSS) was carried out in 1999/2000, although there is considerable debate about the accuracy of the estimates as the NSSO adopted a new methodology for the 55th round (see for example Popli et al., 2005). The NSSO publishes reports on the various surveys and, after a delay, original datasets are available for purchase. One source was of particular use in the context of the present study: the 2002 village facilities (58^{th} round, schedule 3.1).

17th All India Livestock Census

This census was carried out towards the end of 2003, in both rural and urban parts of India. The livestock census consists of three parts: (i) livestock and poultry, (ii) agricultural machinery and implements, and (iii) fisheries. The census results and schedules are posted on the web (DAHD, 2005).

Debroy and Bhandari, 2003

This is an India-wide published study that reviews indicators of deprivation drawing on secondary data sources. The authors use three sets of deprivation indicators: poverty & hunger (head count ratio, food sufficiency), health (infant mortality rate and complete immunization), and education (literacy rate and gross enrollment in elementary school). They categorize a district as most backward whenever it belongs to the lower quartile for four out of the six indicators. They also address gender disparity indicators (sex ratio and ratio of female to male literacy rate). The authors present data for all indicators at district level in annexes.

3.4 Data-mapping and -handling

Data-mapping

As indicated above, the district level was the lowest common level across all sources. For instance, in the case of the NSSO data, the ability to identify the sub-districts, villages, or households where the data were collected had been removed. Other sources, like the 2001 Census, do include sub-district levels for some indicators, whilst the village directory actually provides individual village-level data with village identification. However, where information is available at lower levels (i.e. below the district level), there is no easy way of referencing this information spatially. Geo-referenced sub-district and village boundaries, or comprehensive village locations, are not easily available in India. To generate such information would have involved time-consuming linking of village identifications to spatial locations on the map. The CensusInfo database does provide sub-district maps, but these were not exportable to our GIS software. We therefore decided to use data at the district level, for which we had geo-referenced district boundaries.

A further complication is the lack of standard identifications of spatial units across sources. Each source generally uses its own coding system, compounded by variations in English spelling and sometimes even completely different locality names. We have used the coding convention of the population census, following its state- and district-level identifiers.

The renaming of districts and partitioning of districts posed further complications, particularly when merging datasets from different sources. Old and new names of renamed districts could generally be identified using internet searches. In the case of partitioned districts we attributed the reported value for the original district to all seceded districts. This applies, for example, to three districts in the Livestock Census.

The present study uses the district level as the unit for analysis and for mapping. Most data used are either reported at or can be easily aggregated to district level. Exceptions are variables that cut across districts boundaries, such as some agro-ecological attributes. As indicated below for variables such as rainfall and soil capability, these were regrouped into district-level estimates using GIS tools and weighting by district-area share. Spatial maps at the district level were generated for each of the variables across the five IGP states. Maps depicting each class of livelihood assets are included and discussed in the main text, whereas maps for each of the underlying indicators are presented in Annex 1.

Data-handling

In the present study we distinguish four types of data (Figure 4):

- original individual indicator,
- indexed individual indicator,
- composite asset index for each livelihood asset, and
- overall composite asset index.

All types of data use the district level as the unit of analysis. The original individual indicators vary in source and measurement, and are reviewed in the next section.

Each individual indicator was indexed across all 160 districts of the IGP states. The lowest 10% of values were indexed as value 0.1, the next 10% (10.1-20%) as 0.2, and so on, with the highest 10% indexed as 1.0. Preference was given to such simple indexing over more sophisticated standardization measures (such as Z-scores) in order to maintain a similar spread, across a 0.1-1 range, for all indicators. With the exception of distance to town and scheduled tribes/castes, all variables were indexed positively, i.e. a higher value gives a higher index. The reverse was applied to distance to town and scheduled tribes/castes as these are perceived as negative.

The composite asset index for each class of livelihood asset was calculated as the average of the relevant indexed indicators. Each composite index comprises four indexed variables, with the exception of social capital (three variables) and financial capital (five variables). The underlying index indicators were given equal weight so as to facilitate interpretation and reduce ambiguity. Equal weighting does mean that any increase in the number of variables included automatically reduces the contribution of all variables, leading us to prioritize and retain only 3-5 variables per index. Each composite asset index varies from a minimum of 0.1 to a maximum of 1.0.

The overall composite asset index was calculated as the average of the five composite livelihood asset indexes. The overall index thereby again gives equal weight to each asset category and varies from a minimum of 0.1 to a maximum of 1.0.

With the exception of farm size and herd size, each individual indicator was included only once under the relevant asset. Farm size and herd size are important both as natural and financial capital, and therefore were included in both asset indexes. This also allowed us implicitly to attribute a greater weight to these variables.

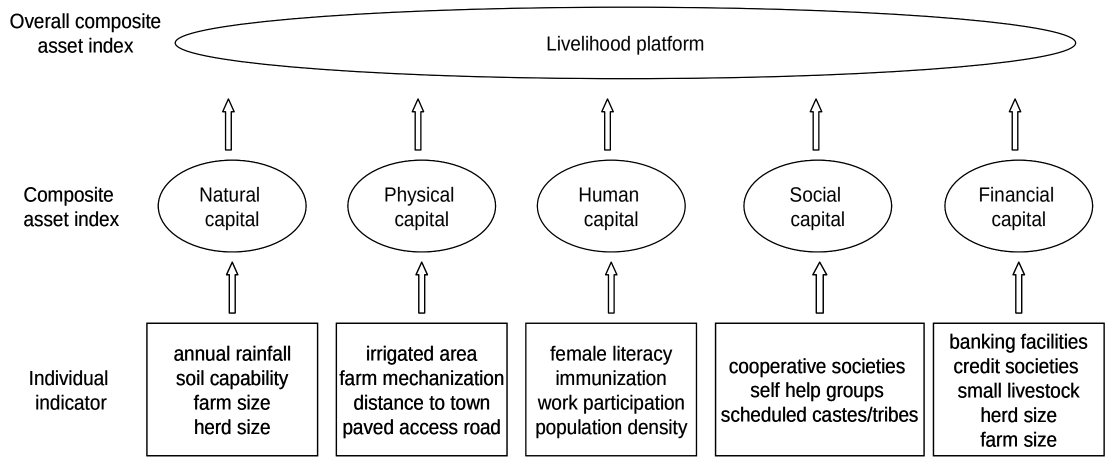


Figure 4 Schematic representation of data types and linkages

3.5 Variables retained

The study retained 18 quantitative, spatially-explicit variables that serve as indicators of the five livelihood capitals. Whilst remote sensing has created substantial amounts of disaggregated biophysical data, the challenge remains of incorporating livelihood data for the other types of assets, namely social, financial, human, and physical. Based on the authors' knowledge, available secondary data, and the need to ensure that there were several indicators for each category of assets, the following list of indicators was selected.

3.5.1 Natural capital indicators

The natural capital index is a composite of four indicators: annual rainfall, soil capability, farm size, and herd size. The first two reflect the qualitative dimension of the natural resource base, i.e. the potential productivity and value of the natural resource base irrespective of access. The last two indicators reflect the quantitative dimension of the natural resource base, i.e. the actual quantities of assets available to individual households.

Annual rainfall

District estimates of annual were derived from 30 year average climate grids (Hodson et al., 2002), with weighting by district area share.

Soil capability

Soil capability is expressed on a continuous three point scale, with a minimum of 1 (low inherent capability) and a maximum of 3 (high inherent capability). The indicator was estimated for each district, drawing on a soil map series for all IGP states on a 1:250,000 scale (NBSS, 1992; NBSS, 1995a; NBSS, 1995b; NBSS, 1997a; NBSS, 1997b) and using the expert opinion of Dr. S.P. Singh and R.P. Dhankar (soil experts from the National Bureau of Soil Survey & Land Use Planning, Nagpur, India) to classify mapped soil types by inherent soil capability. The original soil maps were scanned with a resolution of 600 dpi. Each map was georeferenced using geographic projection and World Geodatic System (WGS) 84 datum. Soil polygons were digitized to generate a vector layer from the georeferenced raster formats. The soil capability polygons were weighted by district area share to generate a district-specific soil capability estimate.

Farm size

Despite the importance of land as an asset for agriculture, farm size estimates are not readily available. The latest available and published farm sizes date back to 1995-96 (e.g. MoA, 2005). We use here a derived farm size calculated as cultivated land area per cultivator. The indicator was estimated using the village-level cultivated area data from the village directory aggregated by district and the reported number of cultivators per district from the population census.

Herd size

Herd size is expressed as the average number of animal units per rural household. The indicator was estimated using the district-level livestock totals from the livestock census and the reported number of rural households per district from the population census. To aggregate across livestock types we converted into animal units using weights of 1.2 for buffalo and crossbreeds, 1 for *desi* (local) cattle and equines, 1.4 for camel, and 0.1 for small ruminants (sheep and goats) and pigs. Livestock are important both as natural and financial capital, and are therefore included in both asset indexes.

3.5.2 Physical capital indicators

The physical capital index is a composite of four indicators: irrigated area share; farm mechanization; distance to nearest town; and paved access road. The first two are prime indicators of investment in productive physical capital for agriculture. The last two indicators reflect proximity to urban centers and the quantity and quality of rural infrastructure. Physical capital has played a large role in technology adoption in India: a study of the introduction of modern crop varieties in Punjab, for example, showed the importance of the availability of irrigation and roads (and fertilizers) in farmer adoption (McGuirk and Mundlak, 1992).

Irrigated area share

Irrigated area share is expressed as the irrigated area divided by total cultivated area. It was estimated using the village-level area data from the village directory and averaging over districts. Irrigated area does not distinguish between sources of irrigation, i.e. canal, bore-hole etc.

Farm mechanization

Farm mechanization is another prime indicator of the farm-level physical capital base. It is expressed as the motorized machine pool divided by total number of rural households. It was estimated using the district-level machine numbers from the livestock census and the reported number of rural households per district from the population census. To aggregate across machine types we converted into tractor units using weights of 1 for tractors and 0.5 for power tillers.

Distance to nearest town and paved access road

A comprehensive road infrastructure is key to poverty reduction. The absence or poor condition of infrastructure, especially of feeder roads and bridges, is a major constraint to agricultural development. Many of India's poorest villages are located 15-20 km from the nearest infrastructure; during the rainy season villagers find themselves completely isolated from more developed areas. "The result is that the members of the unconnected villages remain effectively marginalized from virtually all educational institutions above primary level, from adequate health care facilities, and from important governmental and non-governmental institutions" (Narayan et al., 1999: 37).

Distance to nearest town and a paved village access road are both prime indicators of the community-level physical capital base. The first captures proximity to urban centers and the related density of the road network, whereas the second captures the quality of the rural road network. Distance to town is expressed as the average distance in km from each village to the nearest town, and was estimated using the village-level data on reported distance to nearest town from the village directory and averaging over districts. Paved access road is expressed as the share of the villages within a district having a paved access road, using village directory data.

3.5.3 Human capital indicators

The human capital index is a composite of four indicators: female literacy, complete immunization, rural work participation, and rural population density. The first two indicators reflect the qualitative dimension of the human resource base, respectively its skills and health. The last two indicators reflect the quantitative dimension of the human resource base, i.e. the share of the population actually contributing to the workforce and the population per unit area.

Rural female literacy

Female literacy is an important factor in reducing poverty. Many positive consequences follow from educating girls: better health and education and longer lives for the whole family; more productive workers; and a boost to industrialization and urbanization. The rural female literacy indicator was drawn directly from the population census. It is defined as the percentage of literates in the total rural female population in the age group 7 years and above. Literates are defined as persons aged 7 years and above who can both read and write with understanding in any language (CensusIndia, 2005).

Complete immunization rate

The Millennium Development Goals stimulated the adoption of targets to measure country-level achievements, including achievements on health status indicators such as childhood immunization (Pande and Yazbeck, 2003). Health is a major human asset, with disease and death as significant threats to rural livelihoods. The complete immunization indicator reflects the percentage of children who are immunized for six serious but preventable diseases, including diphtheria, tuberculosis, and poliomyelitis. These diseases have been the cause of high infant mortality and morbidity in India (Debroy and Bhandari, 2003:31-32). The indicator is drawn directly from Debroy and Bhandari (2003, using 2001 data from the National Commission on

Population). The indicator reflects both the health status of children and the availability of health facilities and is therefore taken as a good proxy for overall health status.

Rural work participation rate

Rural work participation rate is drawn directly from the population census. It is defined as the percentage of total rural workers in the total rural population (CensusIndia, 2005). Workers are defined as all persons engaged in any economically productive activity with or without compensation, wages or profit during the preceding year. Work thereby includes effective supervision and direction of work and part time help or unpaid work on farm, in a family enterprise, or in any other economic activity (CensusIndia, 2005). The indicator therefore encompasses the share of the population that is economically active and excludes school-going children, the elderly, the disabled, and the unemployed. It can be perceived as the mirror image of the dependency ratio.

Rural population density

Rural population density is the number of rural persons per square kilometer. This indicator was estimated from population census data by dividing the district-level rural population by the geographical area of the district. In addition to capturing human capital, population density also implies more pressure on natural resources. Some of the latter pressure is also captured by the farm size indicator.

3.5.4 Social capital indicators

Indicators of social capital that met our data selection criteria were particularly scarce. The final social capital index is a composite of three indicators: cooperative societies, self-help groups, and scheduled castes/tribes. The first two indicators reflect social capital in terms of measurable social mobilization at the community level. The last indicator reflects an inherent social characteristic of Indian society.

Cooperative societies and self-help groups

Cooperative societies and self-help groups were retained as two separate indicators of social capital. Both indicators are drawn from the NSSO 2002 village facilities survey. The first is expressed as the share of the surveyed villages within a district having any co-operative society. Similarly, the second is expressed as the share of the surveyed villages within a district having any self-help group.

Scheduled Castes/Tribes

Scheduled Castes and Scheduled Tribes are low-status members of Indian society defined in the Constitution of India and attached schedules (Saxena and Farrington, 2003:1). We include them here as an indicator of negative social capital, reflecting two opposing forces. As members of minority groups, scheduled castes or scheduled tribes are likely to show positive social capital in terms of social cohesion and mutual help. However, and despite positive discrimination, this is generally dwarfed by the still-prevailing social prejudice against these minorities (Borooah, 2005). Belonging to such a group therefore implies significant restrictions and barriers in terms of available economic and social options and may lead to, for example, alcohol abuse (Neufeld et al., 2005) and a life-time of perpetual poverty (Mehta and Shah, 2003). In our study, the scheduled castes/tribes indicator is the sum of two indicators drawn from the population census. It is defined as the proportion of the total rural population within a district belonging to either scheduled castes or scheduled tribes.

3.5.5 Financial capital indicators

Poor people often do not have access to credit. Although lending mechanisms exist, mainstream financial institutions are not oriented towards providing them with the funding they require (Premchander, 2003). Indicators of financial capital that meet our data selection criteria were relatively scarce. Particularly problematic is the informal sphere: while obtaining credit in the informal sector may entail paying higher interest rates (e.g. 21-120% per annum, Erenstein et al, 2007), the flexibility and rural presence of informal credit schemes and moneylenders often make them the only option for the very poor. The final financial capital index is a composite of five indicators: banking facilities, credit society facilities, small livestock, herd size, and farm size. The first two indicators are sources of financial capital at the community level, i.e. potential sources of credit to rural households. The last three indicators reflect sources of financial capital at the household level, i.e. actual productive assets already available to individual households that can be used to mobilize financial capital.

Banking and credit society facilities

Banking and credit society facilities were retained as two separate indicators of financial capital. Both were drawn from the population census village survey. The first is expressed as the share of villages within a district having any banking facilities, including both commercial banks and co-operative commercial banks. Similarly, the second is expressed as the share of villages within a district having any credit society facilities, including agricultural credit societies, non-agricultural credit societies, and other credit societies.

Livestock: small stock and herd size

In addition to being productive natural capital, livestock generally have an important function in rural households as financial capital. On the one hand, livestock can be a source of regular cash income through the sale of animal produce, including milk, eggs, manure, and offspring. On the other hand, livestock often have a financial reserve, savings, and investment function, whereby animals are sold when in need of cash. Two livestock-related indicators were retained as proxies for financial capital. The first is the share of small livestock in overall livestock population, where small livestock includes small ruminants and pigs and livestock population includes all mammals. This indicator captures the tendency for small stock to be more closely associated with the financial capital function of livestock, being less bulky and having shorter gestation. The second indicator is the herd size expressed as animal units per rural household, reviewed earlier as an indicator of natural capital. This captures various underlying financial aspects of rural households, as a proxy for the value of financial reserves, a source of regular cash income and a means to mobilize additional financial resources.

Farm size

We use here a derived farm size calculated as cultivated land area per cultivator, which was reviewed earlier as an indicator of natural capital. Land is the most valuable asset to rural households. It therefore serves as a proxy for the value of financial reserves, a source of regular cash income (either through self-cultivation or renting out) and means to mobilize additional financial resources.

4 Results

This chapter presents the composite indexes of the individual livelihood assets and the overall composite index. We present spatial maps for each class of livelihood asset and a corresponding bar chart to contrast the sub-region averages and highlight statistically significant differences if any. The section presenting the overall composite index also contrasts the overall index against the more conventional monetary poverty indicator.

4.1 Natural capital

The district-level natural capital index varies from 0.25 to 0.90. The spatial map highlights relatively higher indexes in a number of districts in the northwest and the downstream (lower) plains (Figure 5, map). This results in a pattern of relatively high indexes for the two ends of the IGP and relatively lower values for the middle. A sub-region-level comparison highlights that these differences are statistically significant (Figure 5, bar chart). The highest sub-region average is reported for the Lower Gangetic Plains (LGP), the second highest for the Trans-Gangetic Plains (TGP) and the lowest for the Upper Gangetic Plains (UGP) (Table 1). The Middle Gangetic Plains (MGP) has an intermediary value between the TGP and the UGP.

The spatial variation of the natural capital index can be compared with the regional variation of the underlying variables (Annex 1, Maps 1-4 and Table 1). The rainfall gradient is particularly striking, with the 20% of the districts with the highest rainfall (>1370 mm p.a.) largely located in the lower plains in the east and the 20% with the lowest values (< 786 mm p.a.) located in the northwest. The LGP's favorable natural capital index is thereby largely attributable to high rainfall and a relatively favorable soil capability (Table 1). The TGP in contrast tends to score lowest for rainfall and relatively low for soil capability, but this is to a large extent compensated for by a markedly more favorable farm size and a favorable herd size. The low score for the UGP is despite its reasonable soil capability and average herd size, being depressed by the low farm size and its relatively low rainfall.

Table 1 Natural capital indicators at district level by sub-region for the Indian Indo-Gangetic Plains.

	Trans-Gangetic Plains (n=36)	Upper Gangetic Plains (n=40	Middle Gangetic Plains (n=60)	Lower Gangetic Plains (n=13)	Indo-Gangetic Plains mean (±std.dev., p.) (n=149)
Natural capital index	0.58 b	0.50 a	0.54 ab	0.67 c	0.55 (±0.11, 0.00)
1. Annual rainfall (mm per year)	714 a	960 b	1258 c	1570 d	1074 (±339, 0.00)
2. Soil capability index (1 = low and 3 = high)	1.8 a	2.5 b	2.3 b	2.4 b	2.2 (±0.7, 0.00)
3. Derived farm size (cultivated ha per cultivator)	1.63 c	0.69 a	0.74 a	0.98 b	0.96 (±0.51, 0.00)
4. Derived herd size (animal units per household)	3.5 c	2.5 b	2.0 ab	1.9 a	2.5 (±1.2, 0.00)

Note: Data followed by different letters differ significantly (Duncan multiple range test, significance level = 0.10, within row comparison).

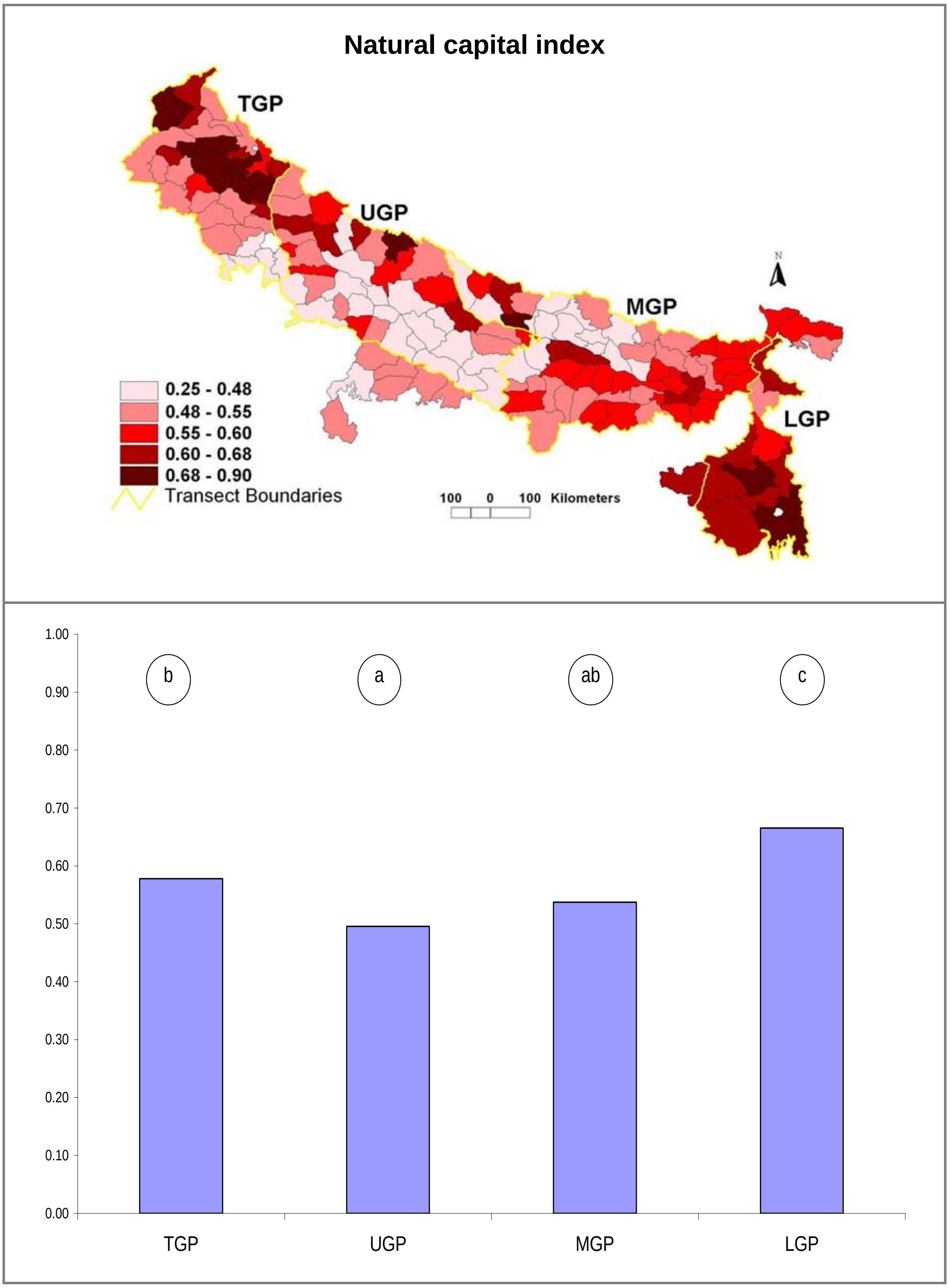


Figure 5 Spatial map of natural capital at the district level in the Indian IGP [top] and transect average [bottom].

Note: Color categories on map refer to quintiles of district index scores.
Bars with different encircled letters differ significantly (Duncan multiple range test, significance level = 0.10).
TGP = Trans-Gangetic Plains; UGP = Upper Gangetic Plains; MGP = Middle Gangetic Plains; LGP = Lower Gangetic Plains.

4.2 Physical capital

The district-level physical capital index varies from 0.1 to 1.0, thereby showing that at least one district scores lowest for each of the four underlying physical asset indicators and at least one district scores highest for each. The spatial map highlights a striking gradient, with high indexes in the northwest decreasing eastwards and downstream to the lowest values (Figure 6, map). A sub-region-level comparison shows that these differences are statistically significant (Figure 6, bar chart). Each sub-region average is significantly different from all others, with the highest reported for the TGP, the second highest for the UGP, followed by the MGP, and with the lowest value for the LGP (Table 2).

The spatial variation of the physical capital index can be compared with the regional variation of the underlying variables (see Annex 1, Maps 5-8 and Table 2). This highlights that the favorable physical capital index for the TGP is attributable to significantly more favorable scores for all four individual indicators. It reflects widespread irrigation (87% cultivated area), high levels of farm mechanization, proximity to urban centers, and nearly all villages having paved access roads (Table 2). The indicators each tend to decline eastwards and downstream. The striking irrigation gradient to a large extent offsets the rainfall gradient discussed earlier.

Table 2 Physical capital indicators at district level by sub-region for the Indian IGP.

	Trans-Gangetic Plains (n=36)	Upper Gangetic Plains (n=40	Middle Gangetic Plains (n=60)	Lower Gangetic Plains (n=13)	Indo-Gangetic Plains mean (±std.dev., p.) (n=149)
Physical capital index	0.83 [d]	0.68 [c]	0.39 [b]	0.26 [a]	0.56 (±0.25, 0.00)
5. Irrigated area share (%)	87 [c]	83 [c]	65 [b]	50 [a]	74 (±18, 0.00)
6. Farm mechanization (tractors per cultivator)	0.13 [c]	0.04 [b]	0.02 [a]	0.01 [a]	0.05 (±0.06, 0.00)
7. Average distance to nearest town (km)	10 [a]	9 [a]	16 [b]	20 [c]	13 (±6, 0.00)
8. Share of villages with paved access road (%)	97 [d]	67 [c]	46 [a]	52 [b]	64 (±24, 0,00)

Note: Data followed by different letters differ significantly (Duncan multiple range test, significance level = 0.10, within row comparison).

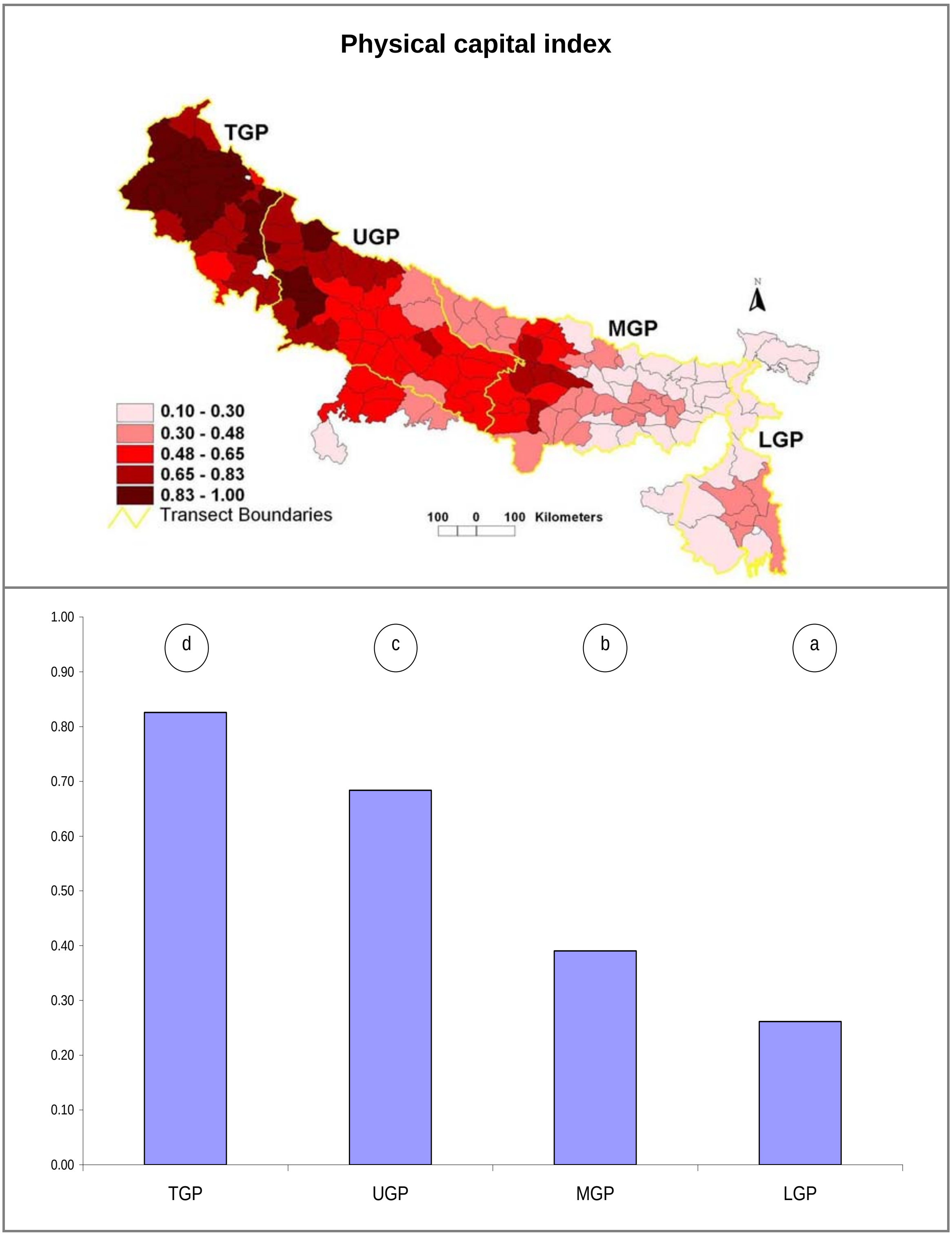


Figure 6 Spatial map of physical capital at the district level in the Indian IGP [top] and sub-region averages [bottom].

Note: Color categories on map refer to quintiles of district index scores.
Bars with different encircled letters differ significantly (Duncan multiple range test, significance level = 0.10).
TGP = Trans-Gangetic Plains; UGP = Upper Gangetic Plains; MGP = Middle Gangetic Plains; LGP = Lower Gangetic Plains.

4.3 Human capital

The district-level human capital index varies from 0.23 to 0.88. The spatial map highlights relatively higher indexes in the northwest and the downstream plains (Figure 7, map), giving a pattern of relatively high indexes for the two ends of the IGP and relatively lower values for the middle. A sub-region-level comparison highlights that these differences are again statistically significant (Figure 7, bar chart). The highest sub-region averages are reported for the LGP and TGP, and the lowest for the MGP and UGP (Table 3).

The spatial variation of the human capital index can be compared with the regional variation of the underlying variables (see Annex 1, Maps 9-12 and Table 3). Rural female literacy best resembles the overall human capital index, with the highest average literacy rates of some 50% in the TGP and LGP and lower values in the intermediate sub-regions. This indicator also shows strikingly low values for the districts along the Nepal border. Rural work participation rate shows a similar tendency to be high at the ends and low in the middle, as does immunization, which is particularly low in the MGP. Rural population density, however, shows a striking west-east gradient, with the TGP averaging 341 inhabitants per km^2 as against the MGP and LGP averaging 795 inhabitants per km^2. The favorable human capital index for the TGP is thereby largely attributable to the relatively favorable other three indicators, which compensate the low population density (Table 3). The LGP has relatively high scores for all four indicators.

Table 3 Human capital indicators at district level by sub-region for the Indian IGP.

	Trans-Gangetic Plains (n=36)	Upper Gangetic Plains (n=40	Middle Gangetic Plains (n=60)	Lower Gangetic Plains (n=13)	Indo-Gangetic Plains mean (±std.dev., p.) (n=149)
Human capital index	0.69 b	0.49 a	0.47 a	0.71 b	0.55 (±0.14, 0.00)
9. Rural female literacy (%)	54 c	39 b	31 a	52 c	41 (±13, 0.00)
10. Complete immunization rate (%)	71 d	41 b	29 a	51 c	44 (±21, 0.00)
11. Rural work participation rate (%)	42 d	33 a	35 b	38 c	36 (±5, 0.00)
12. Rural population density (people per km^2)	341 a	566 b	795 c	795 c	624 (±271, 0.00)

Note: Data followed by different letters differ significantly (Duncan multiple range test, significance level = 0.10, within row comparison).

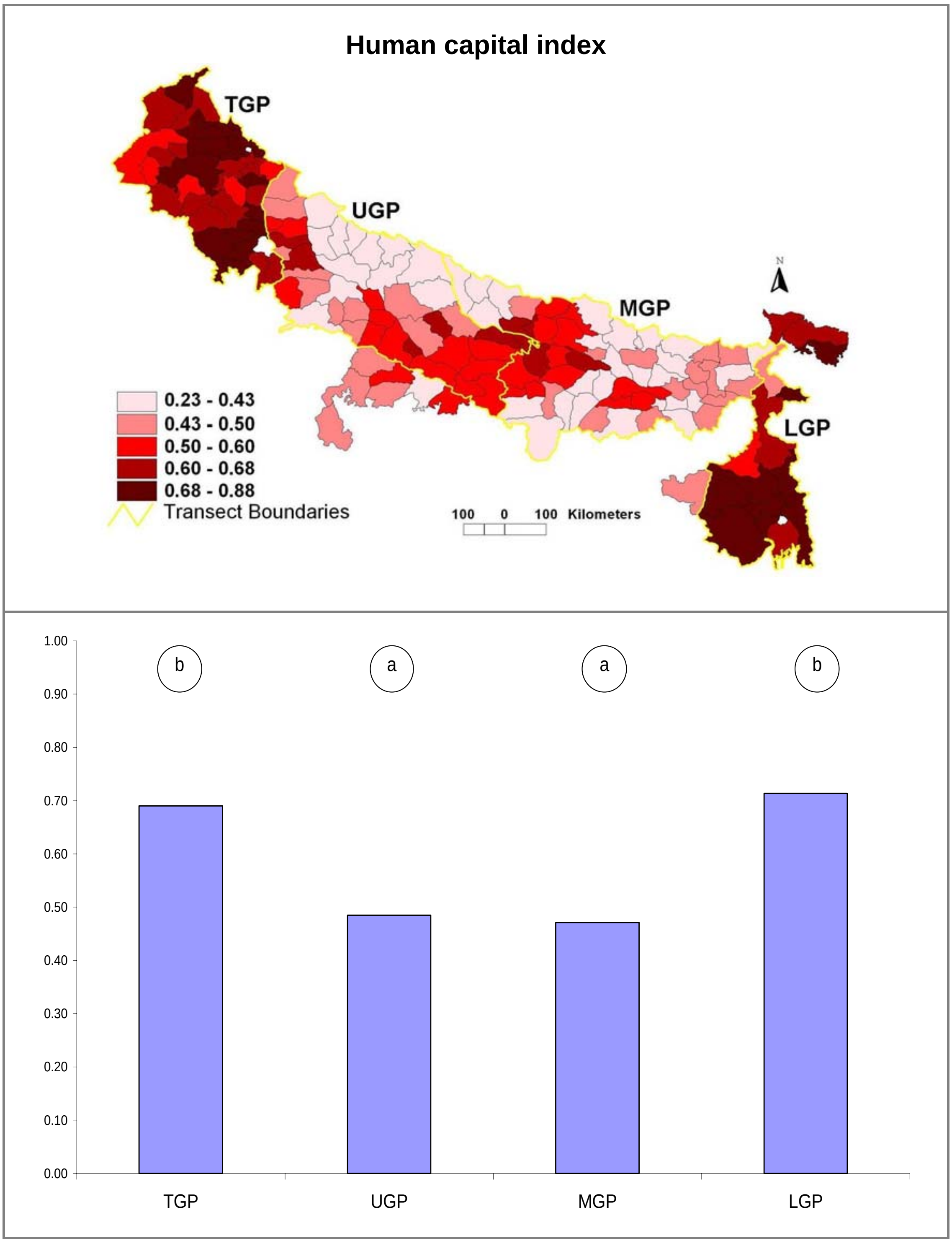


Figure 7 Spatial map of human capital at the district level in the Indian IGP [top] and sub-region averages [bottom].

Note: Color categories on map refer to quintiles of district index scores.
Bars with different encircled letters differ significantly (Duncan multiple range test, significance level = 0.10).
TGP = Trans-Gangetic Plains; UGP = Upper Gangetic Plains; MGP = Middle Gangetic Plains; LGP = Lower Gangetic Plains.

4.4 Social capital

The district-level social capital index varies from 0.2 to 0.9. The spatial map shows a relatively patchy pattern with higher indexes in the northwest (Figure 8, map). A sub-region-level comparison highlights that the TGP and UGP have significantly higher average indexes than the downstream MGP and LGP (Figure 8, bar chart; Table 4).

The spatial variation of the social capital index can be compared with the regional variation of the underlying variables (see Annex 1Annex 1, Maps 13-15 and Table 4). The share of villages with cooperative societies shows a marked eastward decrease from a high in TGP to a low in MGP, increasing in LGP to similar levels to UGP. Social capital is assumed to be negatively associated with scheduled castes/tribes share, which also shows a significant eastward decline from TGP to MGP, but with the highest levels reported further downstream in LGP. The share of villages with self-help groups is high in UGP, contributing to its relatively high social capital. The favorable social capital index for TGP is largely attributable to a high share of villages with cooperative societies (Table 4).

Table 4 Social capital indicators at district level by sub-region for the Indian IGP.

	Trans-Gangetic Plains (n=36)	Upper Gangetic Plains (n=40	Middle Gangetic Plains (n=60)	Lower Gangetic Plains (n=13)	Indo-Gangetic Plains mean (±std.dev., p.) (n=149)
Social capital index	0.57 [b]	0.60 [b]	0.50 [a]	0.49 [a]	0.54 (±0.16, 0.01)
13. Share of villages with cooperative societies (%)	69 [c]	43 [b]	30 [a]	45 [b]	44 (±27, 0.00)
14. Share of villages with self-help groups (%)	24 [a]	39 [b]	15 [a]	25 [a]	25 (±23, 0.00)
15. Scheduled castes/tribes share (%)	26 [c]	21 [b]	17 [a]	30 [d]	21 (±9, 0.00)

Note: Data followed by different letters differ significantly (Duncan multiple range test, significance level = 0.10, within row comparison).

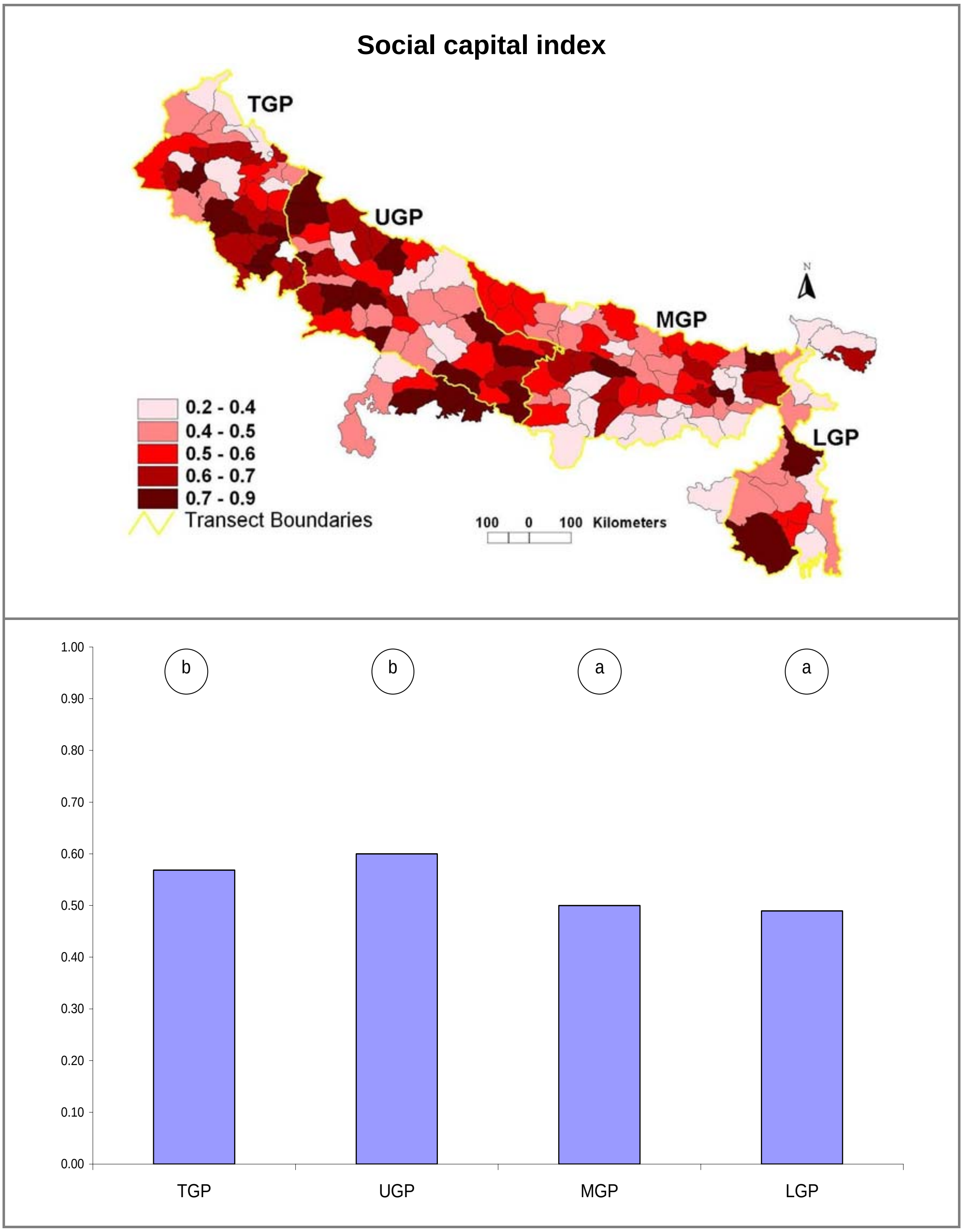


Figure 8 Spatial map of social capital at the district level in the Indian IGP [top] and sub-region averages [bottom].

Note: Color categories on map refer to quintiles of district index scores.
Bars with different encircled letters differ significantly (Duncan multiple range test, significance level = 0.10).
TGP = Trans-Gangetic Plains; UGP = Upper Gangetic Plains; MGP = Middle Gangetic Plains; LGP = Lower Gangetic Plains.

4.5 Financial capital

The district-level financial capital index varies from 0.21 to 0.86. The spatial map highlights relatively higher indexes in the northwest and the downstream plains (Figure 9, map), again resulting in a pattern of relatively high indexes for the two ends of the IGP and relatively low values for the middle. A sub-region-level comparison shows that the TGP has the highest financial capital index, the LGP the next highest, and the UGP and MGP the lowest (Figure 9, bar chart and Table 5).

The spatial variation of the financial capital index can be compared with the regional variation of the underlying variables (see Annex 1, Maps 13-15, 3, 4 and Table 5). The small livestock share shows a marked west-east gradient with a low of 10% for the TGP increasing to 52% in the LGP. However, all other financial indicators tend to be most favorable in the TGP. The share of villages with credit societies best resembles the variation in the overall financial capital index, with the highest average rates of some 40% in the TGP and 20% in the LGP as against only 8-11% in the intermediate sub-regions (Table 5).

Table 5 Financial capital indicators at district level by sub-region for the Indian IGP.

	Trans-Gangetic Plains (n=36)	Upper Gangetic Plains (n=40	Middle Gangetic Plains (n=60)	Lower Gangetic Plains (n=13)	Indo-Gangetic Plains mean (±std.dev., p.) (n=149)
Financial capital index	0.72 [c]	0.43 [a]	0.47 [a]	0.66 [b]	0.53 (±0.16, 0.00)
16. Share of villages with banking facilities (%)	12 [b]	6 [a]	6 [a]	7 [a]	8 (±4, 0.00)
17. Share of villages with credit societies (%)	40 [c]	8 [a]	11 [a]	20 [b]	18 (±16, 0.00)
18. Small livestock share (%)	10 [a]	28 [b]	34 [c]	52 [d]	28 (±15, 0.00)
Derived farm size (cultivated ha per cultivator)	1.63 [c]	0.69 [a]	0.74 [a]	0.98 [b]	0.96 (±0.51, 0.00)
Derived herd size (animal units per household)	3.5 [c]	2.5 [b]	2.0 [ab]	1.9 [a]	2.5 (±1.2, 0.00)

Note: Data followed by different letters differ significantly (Duncan multiple range test, significance level = 0.10, within row comparison).

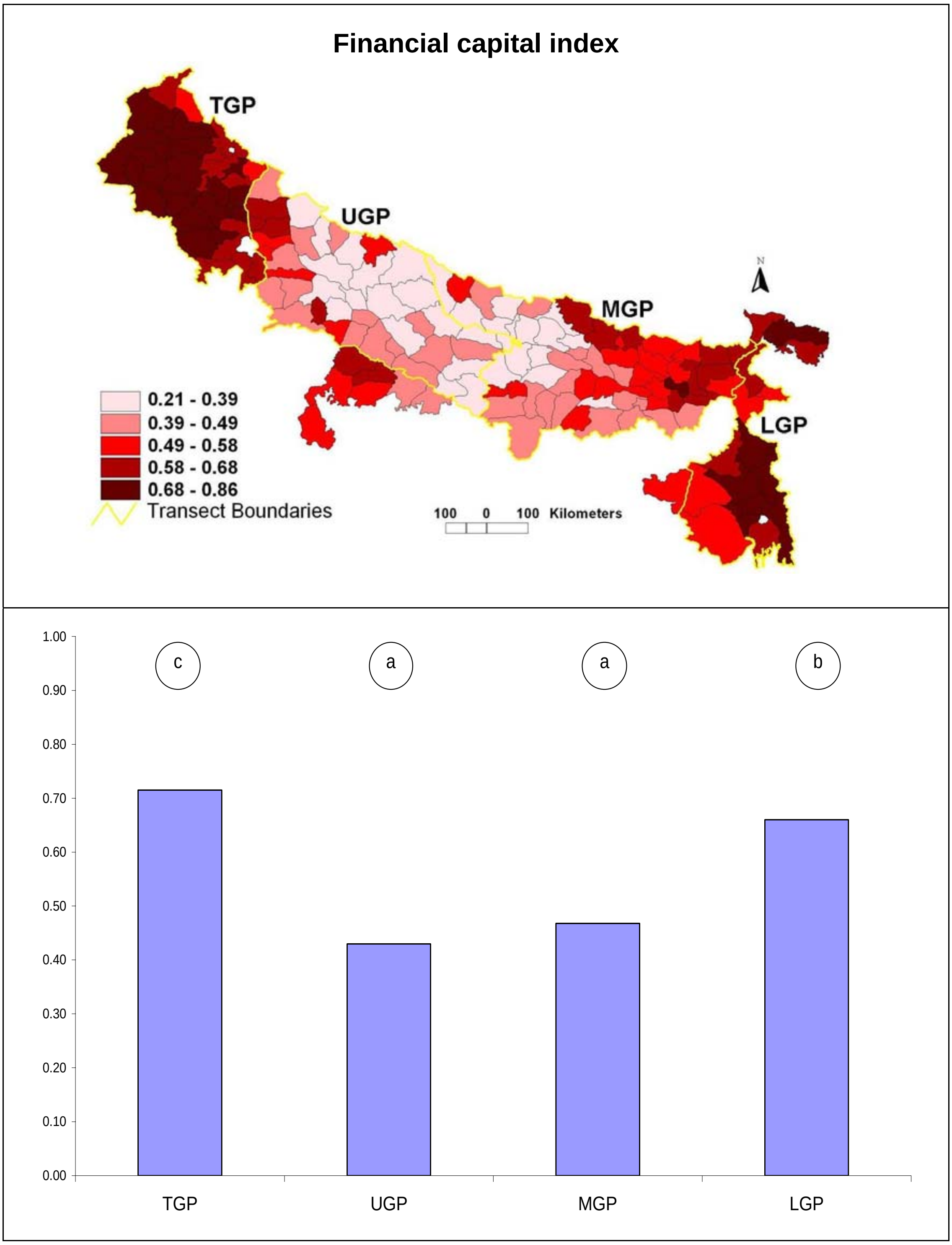


Figure 9 Spatial map of financial capital at the district level in the Indian IGP [top] and sub-region averages [bottom].

Note: Color categories on map refer to quintiles of district index scores.
Bars with different encircled letters differ significantly (Duncan multiple range test, significance level = 0.10).
TGP = Trans-Gangetic Plains; UGP = Upper Gangetic Plains; MGP = Middle Gangetic Plains; LGP = Lower Gangetic Plains.

4.6 Livelihood asset index

The individual capital indexes show significant variation between the sub-regions. A livelihood pentagon allows us to visualize the variation in each of the five classes of assets simultaneously (Figure 10). The pentagon reiterates the relatively favorable asset base of the TGP for all indexes considered. The LGP in contrast has high scores for three types of assets (natural, human, financial), but scores relatively low on social capital and, particularly, physical capital. The UGP combines relatively favorable scores for physical and social capital with relatively low scores for human and financial capital. The MGP tends to score low all round, particularly for physical capital.

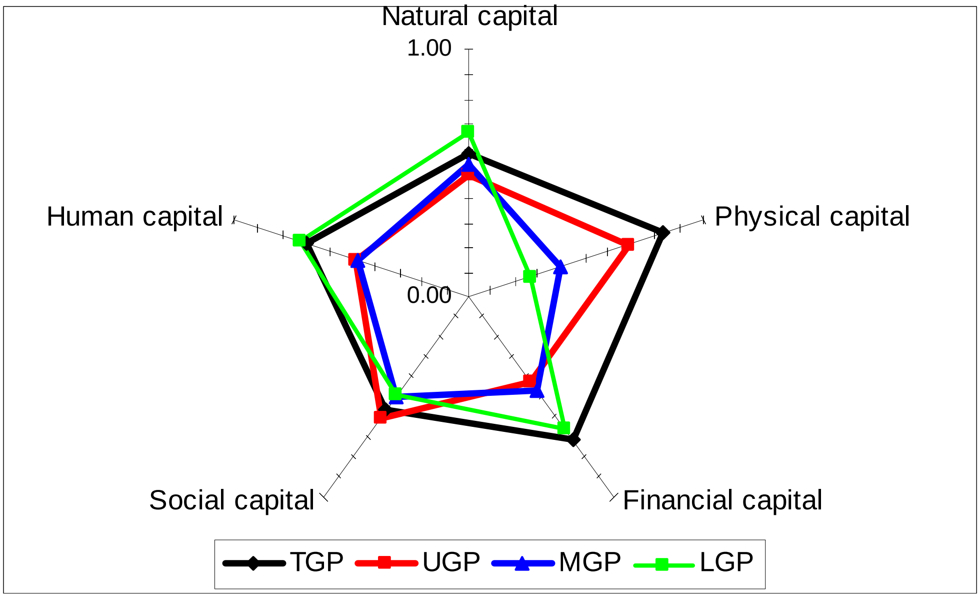


Figure 10 Livelihood asset pentagon for the Indian IGP sub-regions.
Note: TGP = Trans-Gangetic Plains; UGP = Upper Gangetic Plains; MGP = Middle Gangetic Plains; LGP = Lower Gangetic Plains

The district-level livelihood asset index is a composite of the previous five separate asset indexes and varies from 0.33 to 0.86. The spatial map highlights relatively high asset indexes in the northwest, with all TGP districts belonging to the top 40% (Figure 11, map). The UGP and LGP combine contiguous districts with medium level scores (40-80%) with patches of low scores (lowest 40%). The utmost western districts in UGP tend to have favorable asset indexes, partly associated with the proximity to New Delhi. Similarly, in LGP proximity to Calcutta has a largely favorable influence on the asset index. The MGP primarily has districts in the bottom 40% (Figure 11, map). A sub-region-level comparison shows that the TGP has the highest livelihood asset index, the UGP and LGP comprise the middle group and the MGP the lowest (Figure 11, bar chart; Table 6).

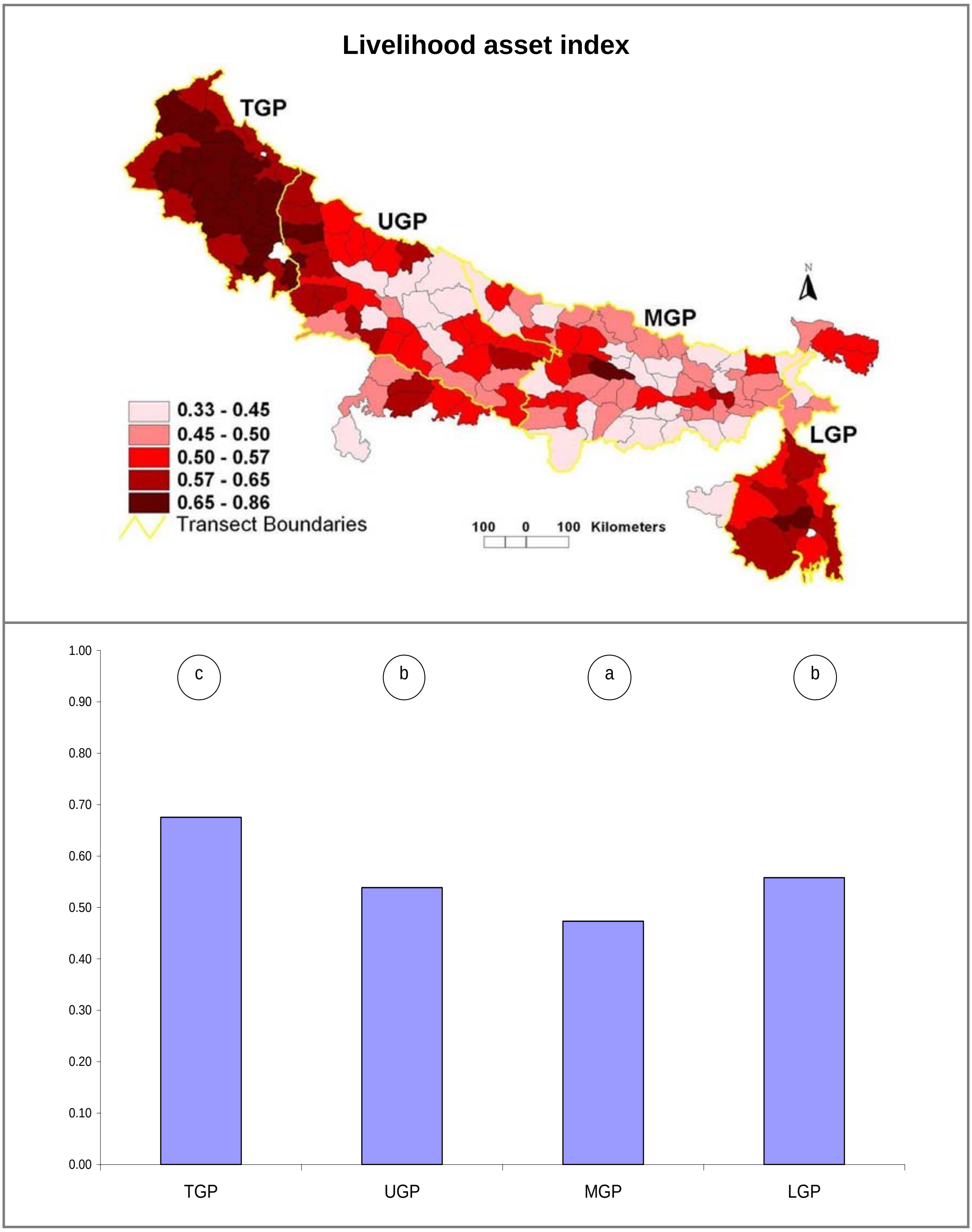


Figure 11 Spatial map of livelihood assets at the district level in the Indian IGP [top] and sub-region averages [bottom].

Note: Color categories on map refer to quintiles of district index scores.
Bars with different encircled letters differ significantly (Duncan multiple range test, significance level = 0.10).
TGP = Trans-Gangetic Plains; UGP = Upper Gangetic Plains; MGP = Middle Gangetic Plains; LGP = Lower Gangetic Plains.

4.7 Livelihood asset index and poverty compared

The livelihood assets are the building blocks of people's livelihoods, whereas poverty is an outcome of people's livelihoods. The livelihood approach therefore predicts that an unfavorable asset base will result in an increased incidence of poverty. In this section we assess our assets index as a predictor for rural poverty in the IGP.

Disaggregated poverty data are not easily available in India. The methodology of the NSSO implies a general reluctance to provide poverty estimates at lower aggregation levels. Debroy and Bhandari (2003) provide one of the few published sources containing poverty data at the district level. They present estimates for head count ratios drawing on the information on household expenditure collected by the NSSO 1999-2000 and using the national poverty line.

The proportion of the population below the poverty line at the district level in the IGP varies from a low of 1.5% to 67%. The spatial map highlights relatively low levels of poverty in the TGP, with most districts in the lowest quintile and all districts within the lowest 2 quintiles (lowest 40%) (Figure 12, map). The other 3 sub-regions present more variation in poverty levels, with each having at least four districts in the poorest quintile; Bihar particularly has large contiguous areas in the poorest quintile. A sub-region-level comparison shows that the TGP has the lowest incidence of poverty, the UGP and LGP have intermediate levels and the MGP the highest (Figure 12, bar chart; Table 6).

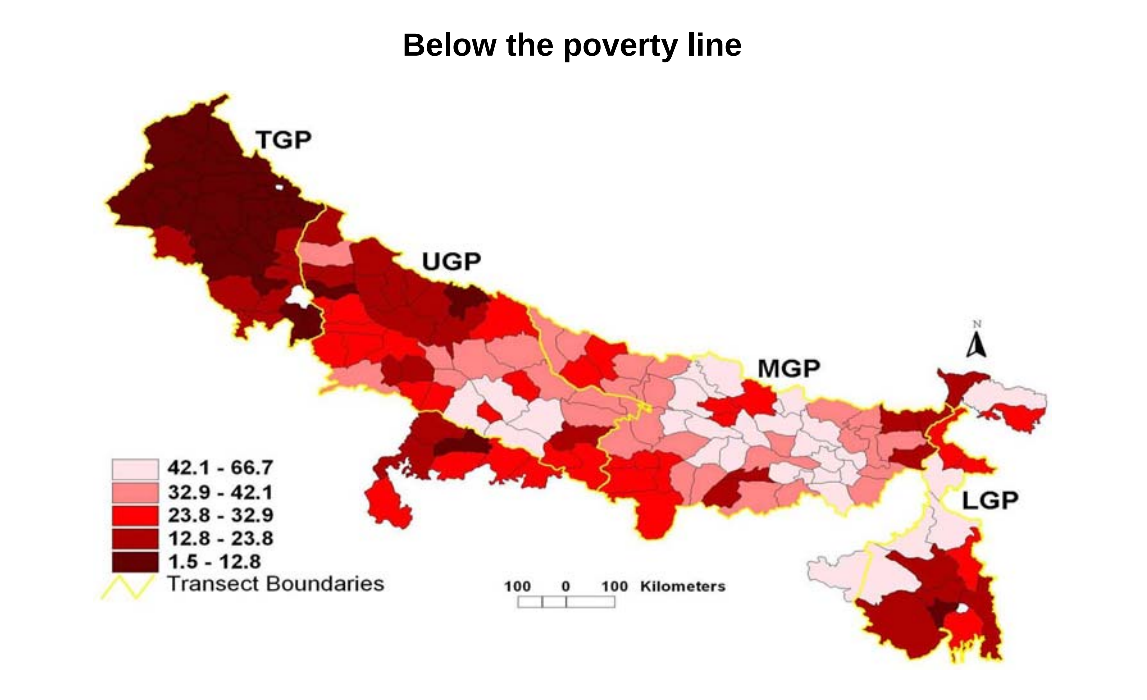
The poverty incidence therefore shows an inverse relationship with the livelihood asset index as expected, poverty peaking in districts where the asset base is lowest and poverty lowest where the asset base is the highest. The asset index and poverty incidence are indeed negatively correlated (correlation coefficient = -0.66, p = 0.00). This is also illustrated in figure 13, where poverty incidence is plotted against the asset index. The linear regression of population below the poverty line (BPL) on the asset index is highly significant and yields an adjusted R^2 of 0.43 (Figure 13).

There is significant correlation between some of the capital indexes, so they cannot be entered simultaneously as individual regressors. However, we can compare the correlations of individual capital indexes with the population BPL to provide an indication of their relative contribution. All correlation coefficients for individual capital asset indexes except social capital are significant and negative. The highest correlation coefficient is with the physical capital index (-0.64), followed by both human and financial capital (each -0.45) and natural capital (-0.21). The combined livelihood asset index therefore provides the best estimate of poverty incidence, although the physical capital index alone provides a good alternate proxy.

Table 5 Livelihood asset index and population below the poverty line (BPL) at district level by sub-region for the Indian IGP.

	Trans-Gangetic Plains (n=36)	Upper Gangetic Plains (n=40	Middle Gangetic Plains (n=60)	Lower Gangetic Plains (n=13)	Indo-Gangetic Plains mean (±std.dev., p.) (n=149)
Livelihood asset index	0.68 [c]	0.54 [b]	0.47 [a]	0.56 [b]	0.55 (±0.10, 0.00)
Population below poverty line (%)	8.3 [a]	27.7 [b]	39.3 [c]	30.3 [b]	27.9 (±15.8, 0.00)

Note: Data followed by different letters differ significantly (Duncan multiple range test, significance level = 0.10, within row comparison). BPL data from Debroy and Bhandari, 2003.



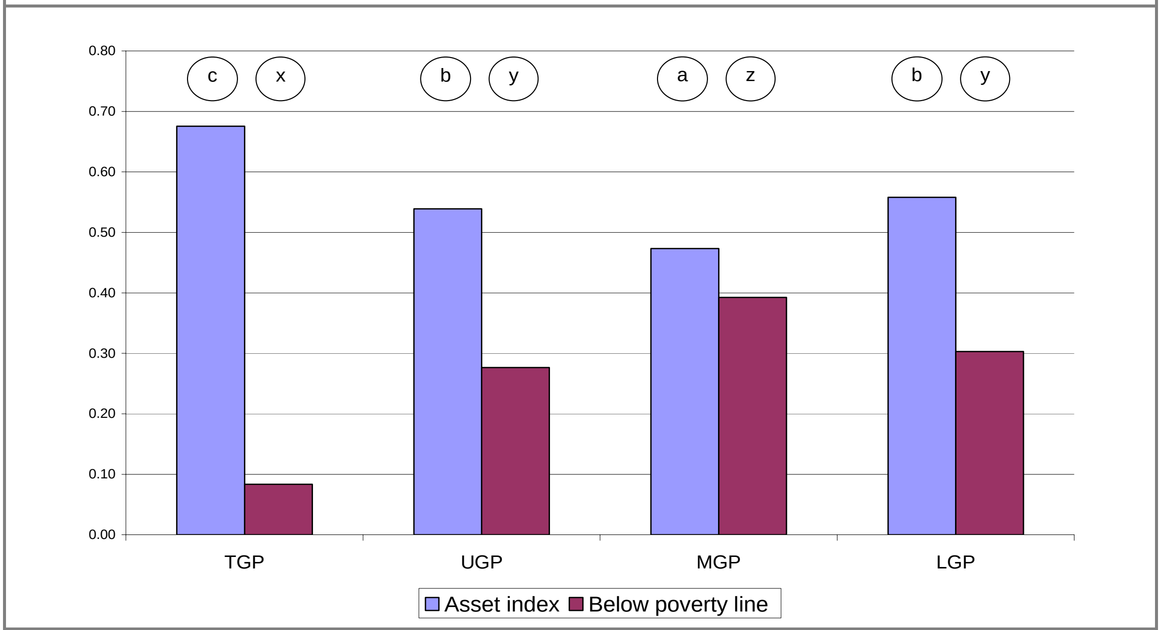


Figure 12 Spatial map of population below the poverty line (BPL) at the district level in the Indian IGP [top] and sub-region averages of population BPL and asset index [bottom].

Note: Color categories on map refer to quintiles of district scores.
Bars with different encircled letters differ significantly (Duncan multiple range test, significance level = 0.10). a,b,c refers to asset index, x,y,z refers to BPL data. BPL data from Debroy and Bhandari, 2003.
TGP = Trans-Gangetic Plains; UGP = Upper Gangetic Plains; MGP = Middle Gangetic Plains; LGP = Lower Gangetic Plains

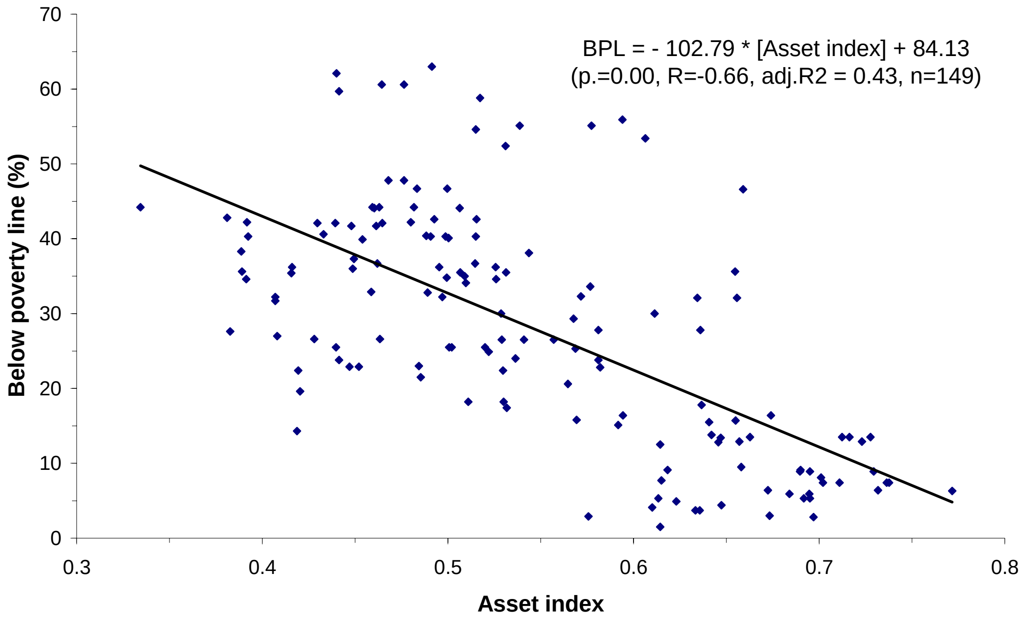


Figure 13 Population below the poverty line against livelihood asset index for each district in the Indian IGP.

5 Discussion

Monetary poverty indicators are often still the preferred measuring stick for assessing developmental progress. In this study we adopted a livelihoods definition of poverty partly because the income-poverty line approach to defining poverty is too narrow and overlooks other aspects of human deprivation (Saith, 2005; Guruswamy and Abraham, 2006). Our results show that a livelihoods asset approach provides a good proxy for monetary poverty measures in the case of the IGP in India. This is particularly encouraging as there has been much debate about the measurement of poverty in India (Deaton and Kozel, 2005; Kijima and Lanjouw, 2003; Popli et al., 2005), particularly over the accuracy of the official poverty figures and comparability over time. Data published by the Indian government using the national poverty line show an acceleration in the rate of poverty reduction from 36% of the population in 1993/94 to 26% of the population in 1999/2000 (Deaton and Kozel, 2005). There are concerns, however, regarding the comparability of the 1993/94 and 1999/2000 NSSO household survey data on which the poverty figures are based (Kijima and Lanjouw, 2003). There is no doubt that poverty is falling in India; what is disputed is the rate at which poverty is declining. In the context of the debate over official poverty figures for India, our livelihood approach offers a complimentary approach.

The livelihood asset approach is thus both a proxy for monetary poverty and a broader poverty measure. It also has a number of other methodological advantages. It circumvents some of the measurement issues with monetary poverty indicators, including which poverty line to use, the choice of consumption over income, the inherent data requirements and the aforementioned comparability issues. Instead, our measure relies on relative asset poverty and on secondary data, although its application is confined to the national or sub-national level.

The use of spatial poverty maps to guide research and development is not new, but it is far less common to base these maps on the five livelihood assets. Another advantage of this approach is that by using livelihood assets it is possible to start disentangling the underlying causes of poverty. It thereby provides more immediate pointers to the policy implications than a purely monetary poverty approach.

The inverse relationship between livelihood assets and monetary poverty (Figure 13) implies that poverty can be alleviated by increasing people’s asset base. The livelihoods approach stresses that each of the five classes of livelihood assets should be seen as complementary building blocks. There are also significant inter-linkages between types of assets. Most obvious, perhaps, is the significant increase in irrigation infrastructure (physical capital) in the TGP to compensate for meager rainfall (natural capital). Another example is that some NGOs in India have promoted micro-finance (financial capital) through women's self-help groups (social capital) (Premchander, 2003; Ghate, 1999). A solid foundation of all five is thus needed for livelihood security and to enable people to rise above the poverty line. The spatial poverty maps illustrate (at a district level) where specific classes of assets are weakest. For instance, the sub-region-level comparisons suggest that the LGP (West Bengal) would benefit from significant investments in physical capital.

The spatial poverty maps therefore give an indication of where development initiatives to build up different assets should focus. This has implications for policy makers, the RWC, and development organizations working throughout northern India. For instance, Fan et al. (1999) analyzed the specific roles that public investment has played in promoting agricultural growth and poverty alleviation in India. They conclude that to reduce rural poverty the Indian government should give high priority to increasing its spending on rural roads and agricultural research and extension, which would also promote the greatest growth in agricultural productivity. Education had the third largest impact on rural poverty, whereas irrigation investment had the third largest impact on growth in agricultural productivity but only a small impact on rural poverty reduction. Another study, however, highlights the appeal of these latter two variables in the design of poverty-targeting programs in India, particularly primary education infrastructure and improved land productivity through irrigation (Shah and Singh, 2004). The mapping of particular variables and classes of livelihood assets can help to distinguish where they are most deficient, and so where investment in different types of asset can have the greatest impact. The mapping thereby enhances both the ability to target investment in different types of asset, and the ability to target investment with more geographical accuracy. The Fan et al. (1999) analysis relied on state-level data, and the disaggregated spatial maps can therefore help target the proposed investments to the district level. Narrower geographical targeting of poverty alleviation programs can improve their coverage, reduce leakage to the non-poor, and reduce program costs (Bigman and Srinivasan, 2002:252).

Limitations of current approach and possible refinements

This study draws on, and therefore is inherently limited by, the available secondary data at the district level. The approach could benefit from a refinement of the indicators used, and other indicators might prove more appropriate in capturing qualitative and quantitative dimensions of the classes of livelihood assets. For example, in the case of natural capital, we used two variables to assess land quality: soil capability and rainfall. Other indicators could be used, such as length of growing period, and/or the indicators used could be refined, for example by assessing soil capability more objectively. Following the livelihoods approach, we assign equal weight to each of the five livelihood assets. However, data limitations mean that each livelihood asset index is not equally robust. For instance, for natural capital numerous indicators are available, whereas for social capital few indicators are available, and for financial capital indicators are somewhat skewed towards the formal sector and visible assets. Adding additional indicators dilutes the contribution of each. Weighting could compensate for this but makes the approach more arbitrary. For instance, Bansil (2006) has used 74 variables in 9 categories for his composite human poverty index. Whereas these may provide pointers to other potential indicators, the applied weights to categories and the inclusion of some of the variables become somewhat subjective.

The currents study uses the district level as the unit of analysis, primarily dictated by the availability of data. The decision to use aggregated as opposed to household-level data does clearly lead to some loss in precision (Minot and Baulch, 2005) due to the livelihood asset heterogeneity within districts, villages, and households. District level data and averages can therefore mask pockets of poverty at lower aggregation levels in well- and poorly-endowed districts alike throughout the IGP. As indicated by Bigman and Srinivasan (2002:253), there is a "*wide spread of poverty in all states and districts in India where all too often one finds a slum next to a fancy apartment building*". These pockets are not captured by the poverty maps, particularly when they exist in otherwise well-off districts, and deserve the attention of policy makers, researchers, and development practitioners. Future studies may want to explore the use of the sub-district as level of analysis, which is do-able given time and effort and may add to the precision.

The current set of spatial poverty maps are a snapshot of the levels of assets; they do not capture any trends. While the maps are a useful tool, their utility would be enhanced if put in a dynamic perspective and linked to underlying trends. Dependent on data availability, maps could be generated for different points over time to illustrate the spatial dynamics of individual assets, their relative contribution and linkages to poverty. For example, the current relatively favorable asset base and agricultural productivity of the TGP is being undermined by the degradation of the natural resource base. In order to boost agricultural productivity and enhance the use of irrigation to compensate for low inherent natural capital, state governments provided a one-time investment subsidy for drilling wells, and priced electricity for electric pump use at very low or zero rates (World Bank, 2005b). Such government subsidies, however, are threatening the longer-term sustainability of agricultural production in many areas, with inefficient use of water leading to salinity and waterlogging problems in canal-irrigated areas, and over-extraction of groundwater resources.

Reassessing poverty-asset linkages

The present study shows an inverse relationship between livelihood assets and monetary poverty. The link, however, between livelihood assets and livelihood outcomes (poverty reduction) is not straightforward, and a sole focus on assets ignores the drivers and modifiers that are addressed in the livelihood framework (e.g. Figure 2; Ellis, 2000; DFID, 2003). We need to better understand how livelihood assets contribute to the adoption and adaptation of technologies and knowledge, and so to impacts on poverty in the IGP, and how these linkages are influenced by the cooperation and interaction of farmers, private firms, public officials, and technical specialists.

An impact pathway or network describes the dominant chain of events linking research outputs, such as resource-conserving technologies or knowledge, to farm household-level impact. Generally, impact pathway analysis provides insight into the dominant links and critical roles of the key actors leading to the adoption and better management of improved technologies and knowledge in farmers' fields.

The agriculture sector in the IGP is also dynamic and ever-changing, challenging the dominant and relative roles of wheat, rice, and livestock on small farms produced both for home consumption and cash. Beyond the farm gate, agricultural intensification and diversification generate significant employment and income along the commodity value chains. Extra farm income stimulates the local non-farm economy, creates new jobs, and reduces poverty, especially among the landless—often referred to as the "poorest of the poor" (Ellis, 1999). Empirical studies show that every additional US$1 of farm production can generate another US$3 of growth in the rural economy (Watkins and Von Braun, 2003). Meanwhile, increased and more reliable yields of wheat and rice which assure household food security can also encourage diversification to other income-generating farm and off-farm enterprises.

The complex web of interactions between researchers, extension agents, equipment manufacturers, input suppliers, farmers, traders, processors, retailers, and consumers, is sometimes considered as an innovation system (Hall et al., 2005). It would be an impossible task to document comprehensively and analyze all the direct and indirect impacts of building up farm households' levels of natural, financial, physical, social, and human capital in the IGP. However, the present spatial mapping approach would benefit from complementary efforts to map the chain of events linking research outputs through their uptake by intermediate actors (generating "outcomes") to their eventual adoption by end users (generating "impacts"). This calls for an assessment of previous development/research experiences in order to understand the rationale behind farmers' engagement with and reaction to research and/or development initiatives. In this respect, a separate companion study (Raina and Sulaiman, 2007) synthesizes some of the livelihood outcomes, innovation systems, and impact pathways within the IGP in order to shed light on farmers' diverse and complex livelihood decisions.

Farmers have diverse livelihood strategies and this influences their need for, and ability to adopt and benefit from, resource-conserving technologies and knowledge generated by the RWC. In order to target its resource-conserving technologies more effectively, the RWC and its partners need a better understanding of the innovation systems and impact pathways that link research outputs to farm-level impacts, including improved household livelihoods. For example, while the promotion of labor-saving technologies may be advantageous for producers in the TGP, large-scale adoption of these technologies leads to fewer jobs for migrant laborers from the MGP. In this case the adoption of the technologies may have a negative impact on the livelihoods of these laborers. For the RWC to make a difference in poverty alleviation there is a need to consider the potential direct and indirect impacts of research-for-development initiatives. In the end, the decisions of millions farmers throughout the IGP determine whether resource-conserving technologies are adopted, impacts registered, poverty reduced, and livelihoods improved. This approach signifies a significant paradigm shift, in moving away from a crop and technology focus to a people-centered livelihoods focus, and from a linear understanding of technology dissemination to a non-linear understanding of how farmers innovate and systems change.

Implications of approach

The spatial poverty maps provide a foundation for priority-setting and targeting within the IGP. The present approach thereby provides a tool to incorporate livelihood and poverty considerations, but does not set priorities as such. Priority-setting depends on an assessment of the value of alternative investments, which captures their relative potential benefits and effectiveness, given existing impact pathways. Priority-setting and targeting would therefore also benefit from a better understanding of the asset-poverty linkages and the trade-offs between alternative investments, as these are still not fully understood in the context of the IGP.

For instance, land and water resource degradation threaten the longer-term sustainability of agricultural production in the TGP, the current cereal bowl. Such ongoing natural resource degradation undermines future national food security, with implications for the rural and urban poor alike. Some stakeholders have called for a shift of the cereal bowl to the eastern region of the country, including eastern Uttar Pradesh, Bihar, and West Bengal. The eastern IGP, with its highly fertile soils and relatively plentiful water supply, can support cereal systems on a more sustainable long-term basis than the western IGP (World Bank, 2005b). Such a shift and intensification would also have significant positive implications for poverty alleviation. Our maps make a number of these relationships spatially explicit and can help guide the discussion. However, the maps as such remain only one input. Complementary research is still needed to rigorously assess the full implications of such a spatial shift, including the impact of climate change, as this will likely exert increasing pressure on the productivity of wheat, particularly in the eastern plains (Ortiz et al., 2006). Similarly, our maps can guide but not answer the discussion as to whether the RWC should invest primarily in relatively marginal areas in the MGP as against the more favorable TGP, and what the relative emphasis should be in terms of poverty alleviation (MDG 1) and environmental sustainability (MDG 7) (RWC, 2006).

The methodology used in this study, along with the spatial poverty maps, provides a framework for future research and development work. The livelihood framework and data at the district level illustrate the linkages between the micro and macro environments. The approach provides for the possibility of using local level studies/data as building blocks contributing to higher aggregation levels, and vice versa. The framework can therefore guide local interventions and data collection needs. It provides baseline livelihood data and contributes to ex-ante and ex-post impact assessment. It also helps to identify bottleneck assets, to prioritize intervention needs, and to enhance targeting. In this respect, the study also calls for making socio-economic research spatially explicit, thereby enhancing its contribution to a spatially explicit knowledge base to support research decision-making in general, and priority-setting and targeting in particular.

A livelihoods approach to poverty reduction entails taking on board variables linked to themes that often do not appear on disciplinary scientists’ radars. A challenge for the RWC is to accept that agricultural technologies promoted throughout the IGP may not always be the key to poverty alleviation. In some cases the most pressing needs may be to improve health and education. The spatial maps and the livelihood framework, therefore, have the potential to bring about synergies between agriculture-focused work and other disciplines. Hence, for policy makers, the maps can encourage a more judicious targeting of resources and interventions.

Although the study focuses on the IGP, the approach has wider applicability and could be extended to other areas. This would test the sensitivity of the approach to increased heterogeneity. The IGP encompasses a large geographical area with significant diversity, but it is nonetheless a plain area and is probably less heterogeneous than some of the rainfed undulating or mountainous landscape. Extension of similar studies to other areas may also need to draw on alternative variables that prove to be more suitable because of data availability.

6 Conclusion

The spatial mapping approach developed for the IGP provides a very useful tool to incorporate livelihood and poverty considerations into R&D priority-setting and targeting. It provides a practical application of spatial poverty maps based on a broad definition of poverty, which provides more immediate pointers to policy implications than a purely monetary definition. The livelihoods approach ensures an applied, holistic, and cross-disciplinary approach to priority-setting and targeting. Having mapped the livelihood assets, we now need to better understand the asset-poverty linkages and the trade-offs between alternative investments so as to enhance R&D priority-setting in the IGP.

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Annex 1 Spatial maps for individual indicators

Natural capital indicators:

1. Annual rainfall (mm per year)
2. Soil capability index (1: low; 3: high)
3. Derived farm size (cultivated ha per cultivator)
4. Derived herd size (animal units per household)

Physical capital indicators:

5. Irrigated area share (%)
6. Farm mechanization (tractors per cultivator)
7. Average distance to nearest town (km)
8. Share of villages with paved access road (%)

Human capital indicators:

9. Rural female literacy (%)
10. Complete immunization rate (%)
11. Rural work participation rate (%)
12. Rural population density (people per km^2)

Social capital indicators:

13. Share of villages with cooperative societies (%)
14. Share of villages with self-help groups (%)
15. Scheduled castes/tribes share (%)

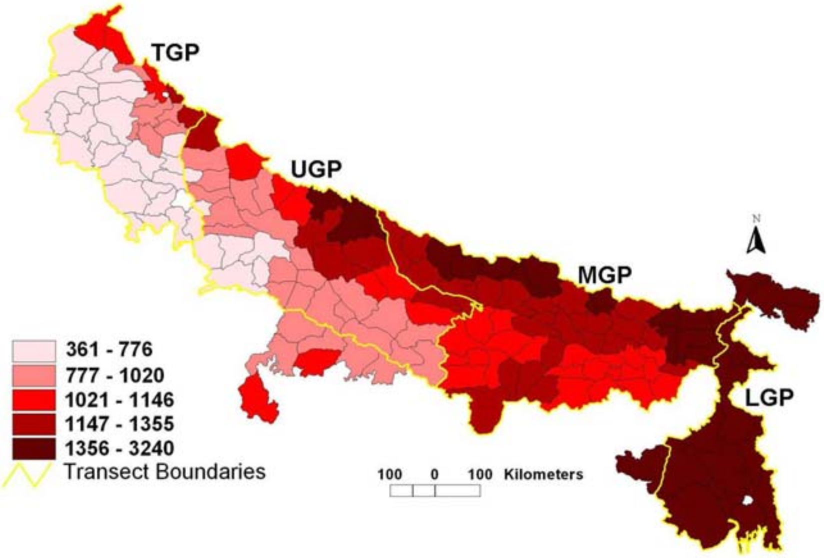
Financial capital indicators:

16. Share of villages with banking facilities (%)
17. Share of villages with credit societies (%)
18. Small livestock share (%)

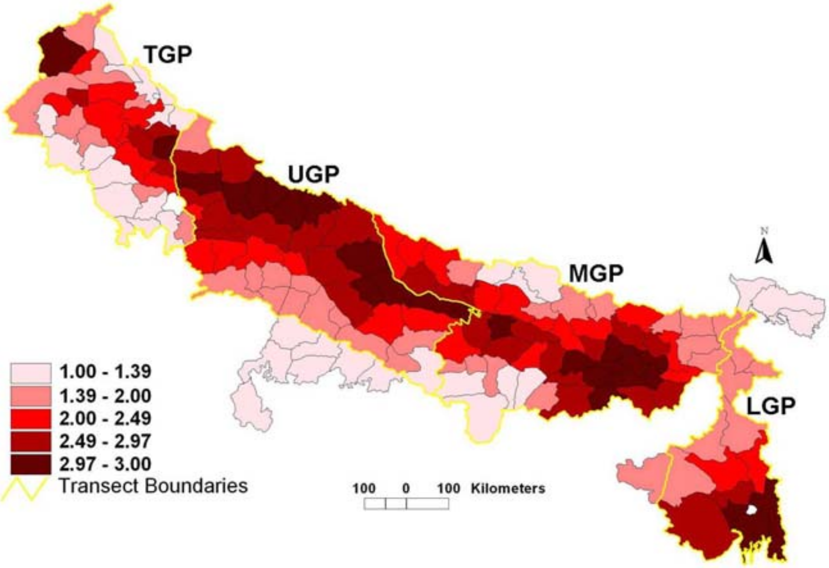
3. Derived farm size (cultivated ha per cultivator)
4. Derived herd size (animal units per household)

Sources vary by indicator: see Chapter 3 for details.

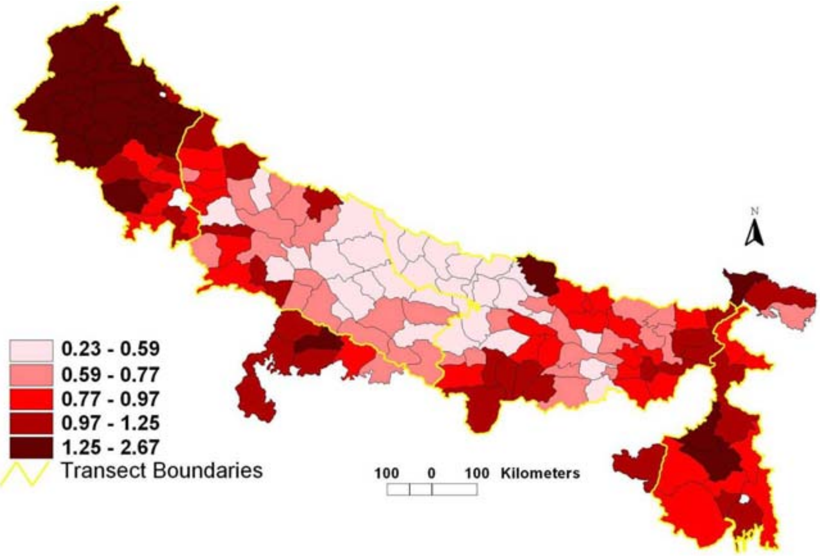
1. Annual rainfall (mm per year)



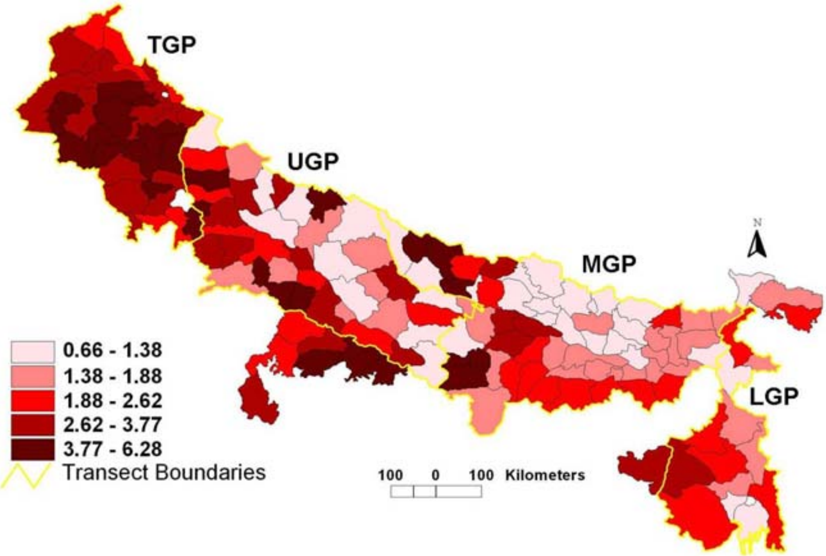
2. Soil capability index (1: low; 3: high)



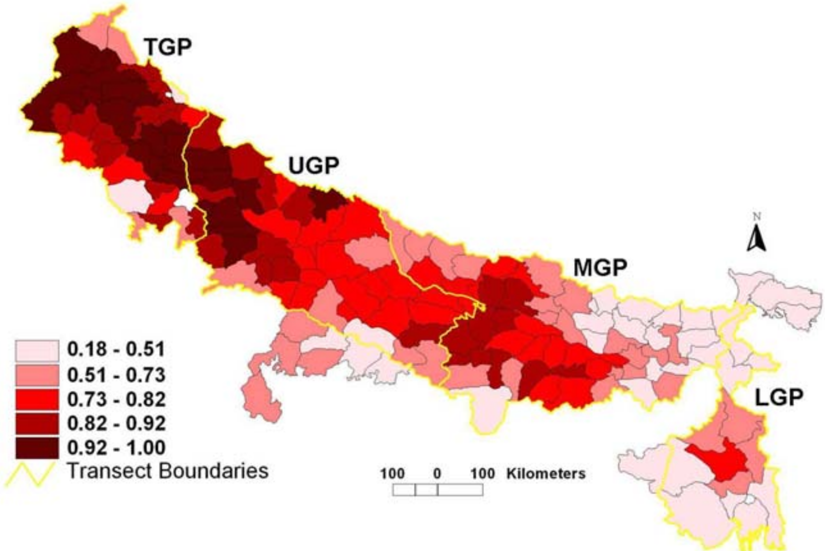
3. Derived farm size (cultivated ha per cultivator)



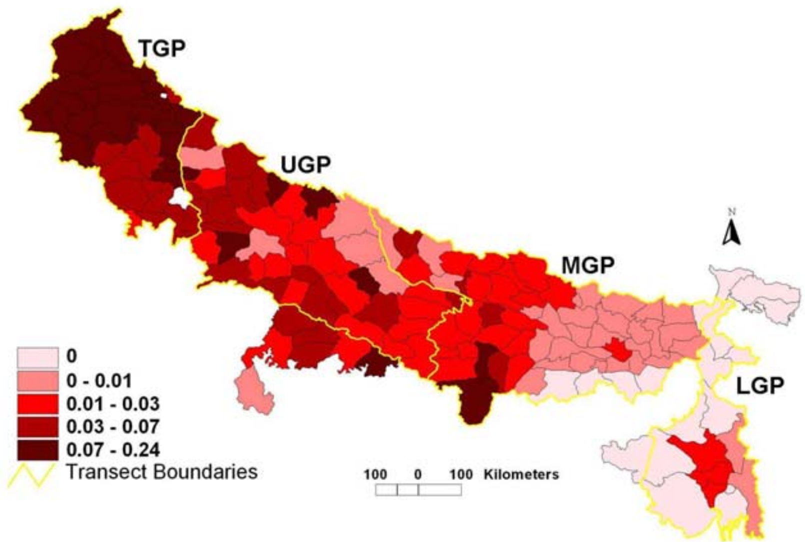
4. **Derived herd size (animal units per household)**



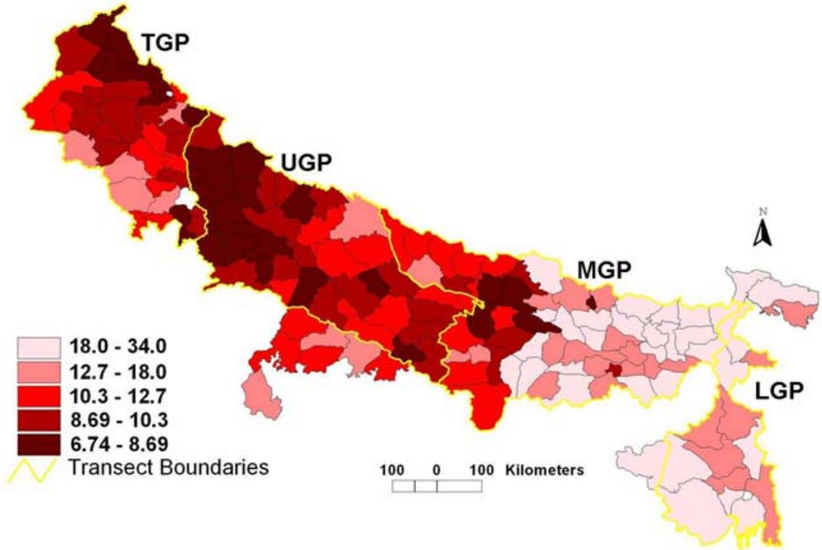
5. **Irrigated area share (%)**



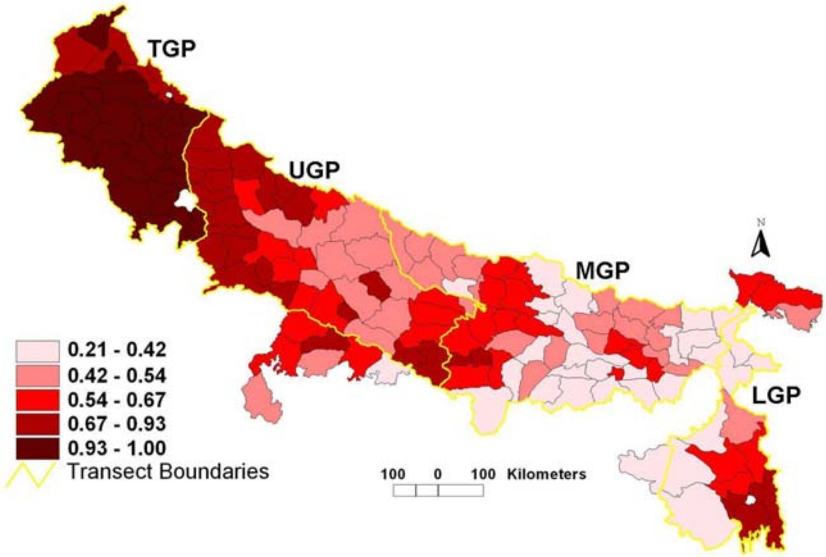
6. **Farm mechanization (tractors per cultivator)**



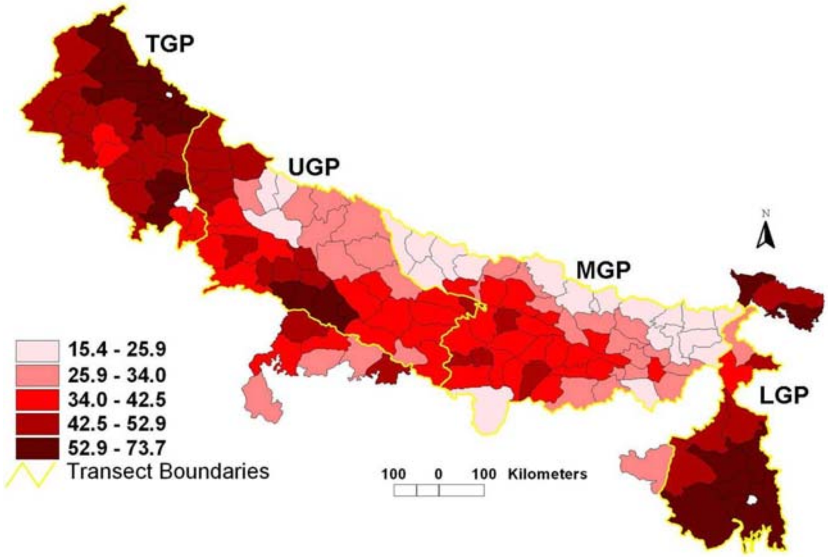
7. Average distance to nearest town (km)



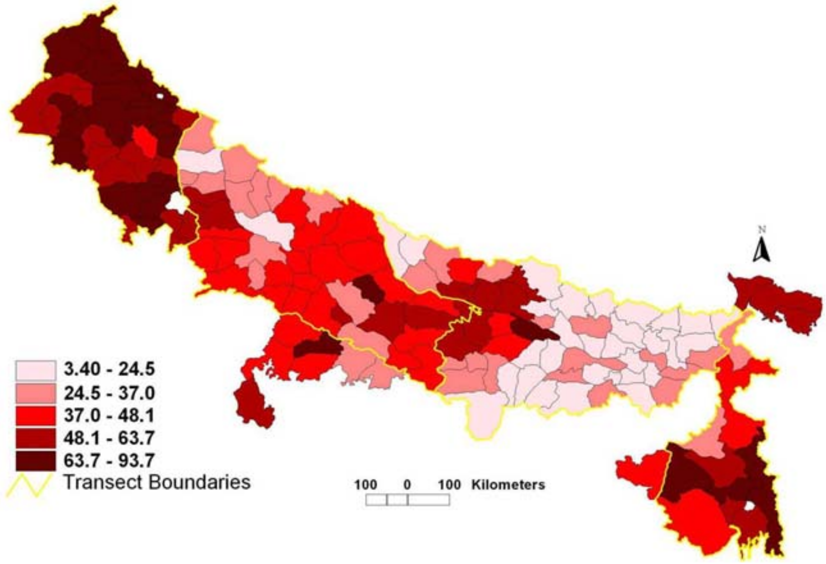
8. Share of villages with paved access road



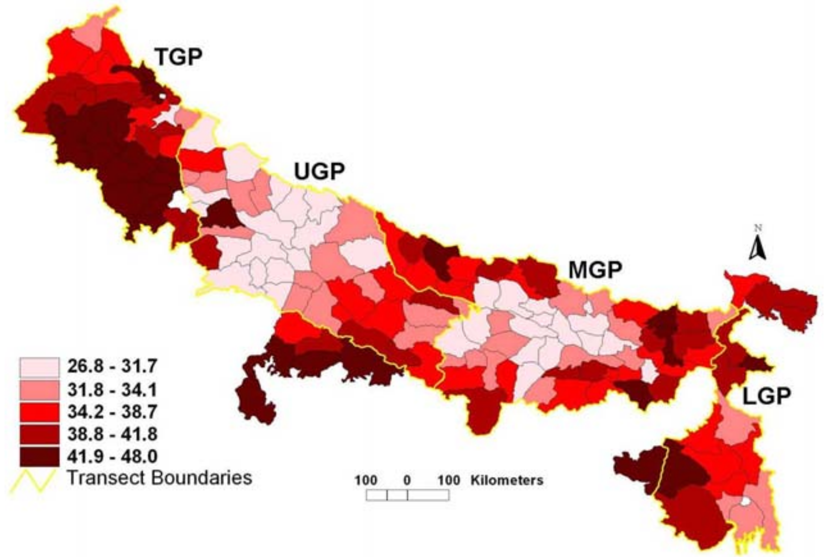
9. Rural female literacy (%)



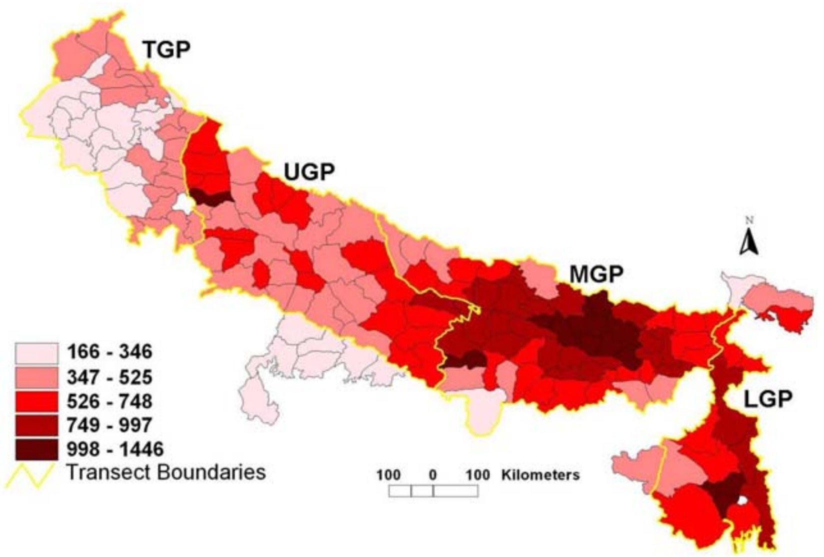
10. Complete immunization rate



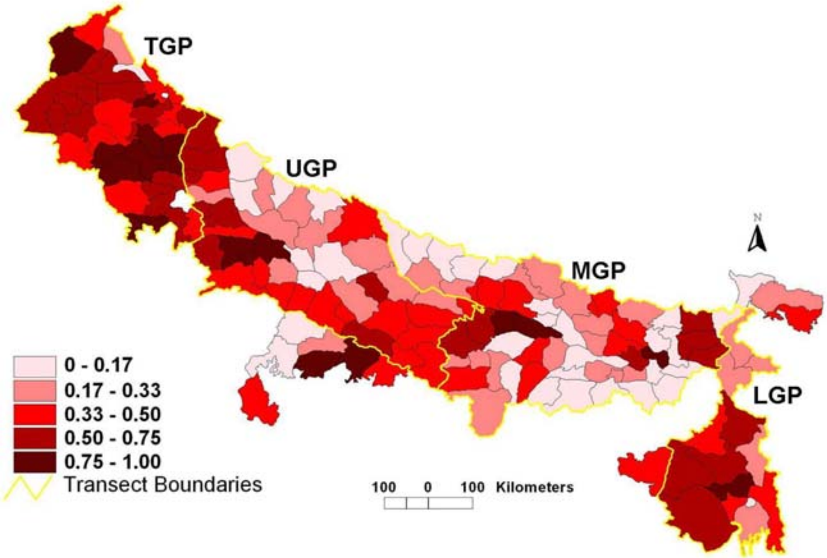
11. Rural work participation rate



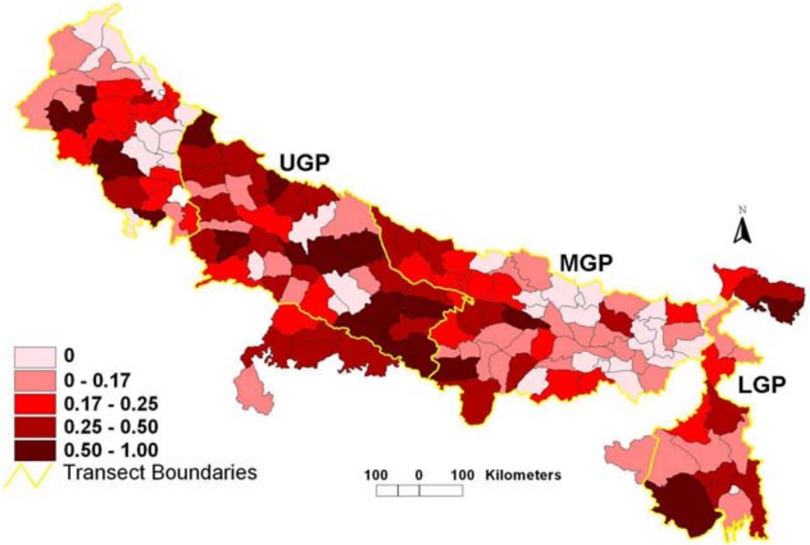
12. Rural population density (people per km²)



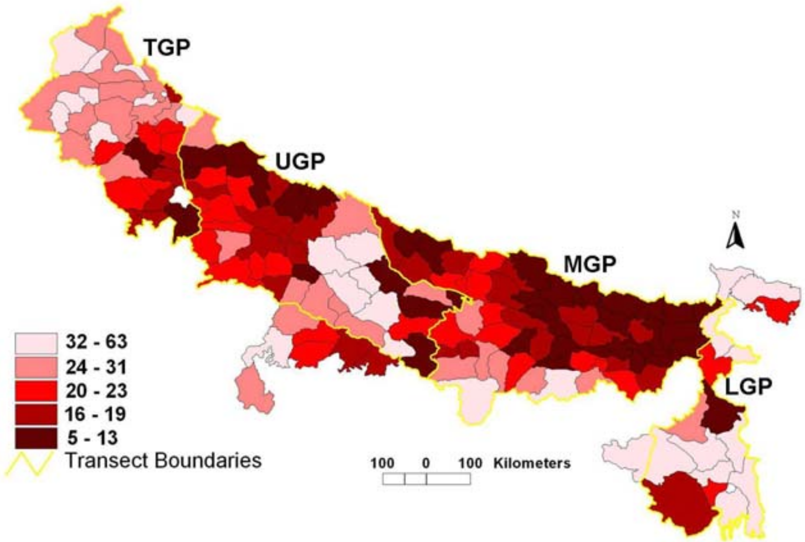
13. Share of villages with cooperative societies



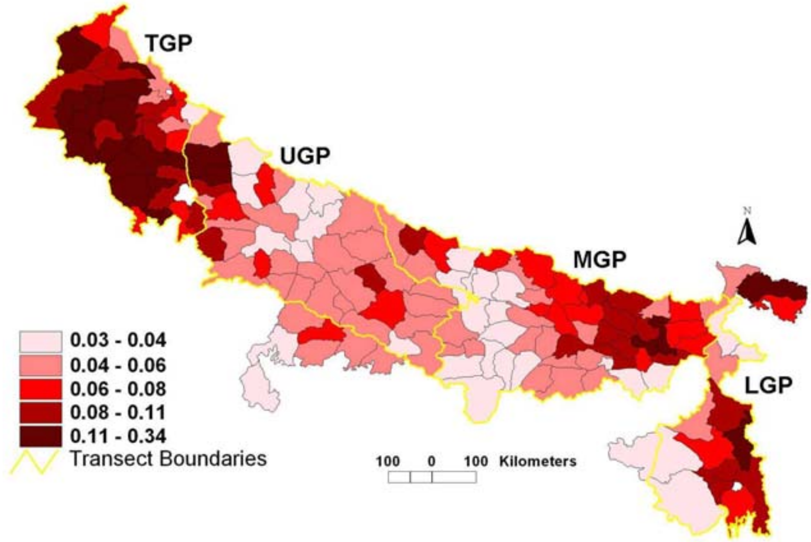
14. Share of villages with self-help groups



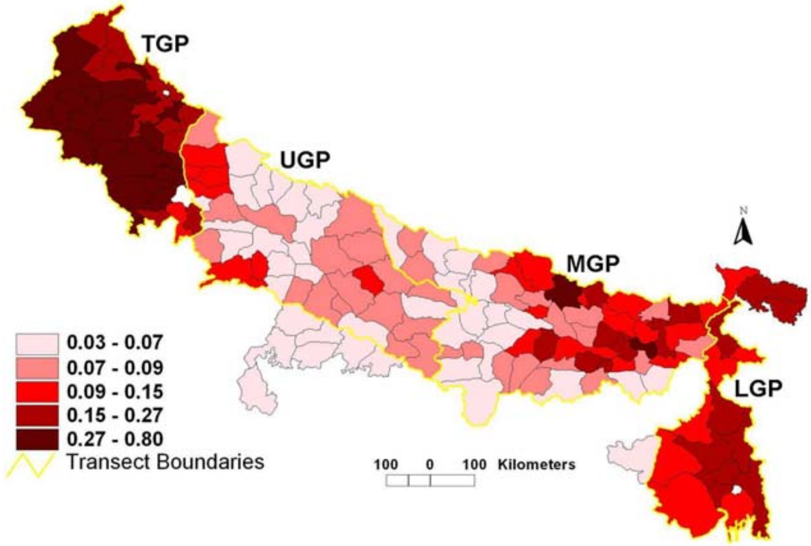
15. Scheduled castes/tribes share



16. Share of villages with banking facilities



17. Share of villages with credit societies



18. Small livestock share