Crop-livestock interactions and livelihoods in the Indo-Gangetic Plains, India: **A regional synthesis**

Olaf Erenstein, William Thorpe, Joginder Singh and Arun Varma

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Crop-Livestock Interactions Scoping Study: Synthesis [1]

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December 2007

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[1] This study was jointly funded by the United States Agency for International Development (USAID), the International Livestock Research Institute (Nairobi, Kenya - ILRI), the International Wheat and Maize Improvement Centre (Texcoco, Mexico – CIMMYT) and the CGIAR Systemwide Livestock Programme (SLP). The views expressed in this report are those of the authors and do not necessarily reflect the views of USAID, ILRI, CIMMYT, SLP or the Rice-Wheat Consortium of the Indo-Gangetic Plains (RWC, New Delhi, India).

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Correct Citation: Erenstein, O., W. Thorpe, J. Singh, and A. Varma. 2007. *Crop-livestock interactions and livelihoods in the Indo-Gangetic Plains, India: A Regional Synthesis*. Mexico, D.F.: CIMMYT.

ISBN: 978-970-648-162-7

AGROVOC Descriptors: Agricultural development; Crop management; Cropping systems; Crop residues; Livestock management; Environmental factors; Feed crops; India

AGRIS Category Codes: E16 Production Economics
F01 Crop Husbandry
L01 Animal Husbandry

Dewey Decimal Classification: 630.54

Layout/design: Eliot Sánchez Pineda

Printed in New Delhi.

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Foreword

The present study is the fifth in a series of five reports for the Crop-Livestock Interactions Scoping Study. Each of the first four reports describes a particular subregion of the Indo-Gangetic Plains in India: the Trans-Gangetic Plains (TGP, Punjab [the Indian Punjab throughout this report] and Haryana; Erenstein et al. 2007c), Uttar Pradesh (Singh et al. 2007), Bihar (Thorpe et al. 2007), and West Bengal (Varma et al. 2007). This fifth report synthesizes across the four subregions. To facilitate write-up, synthesis and future reference, all the reports follow a similar outline and table format. This implies some repetition between reports, but this was still preferred to a single bulky report in view of the richness and diversity of the information so as not to lose the local insights and relevance. Chapter 1 (Introduction), chapter 2 (Methodology), the action research needs for the IGP (part of 7.3), and most of the annexes are largely identical in each of the reports. Each report can be read as a stand-alone report.

Acknowledgements

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Acronyms

CIBR	Central Institute on Buffalo Research (Hisar, Haryana)
CIMMYT	International Wheat and Maize Improvement Centre (Texcoco, Mexico)
GCA	gross cropped area
FCI	Food Corporation of India
ha	hectare/s
HAU	Haryana Agricultural University
IGP	Indo-Gangetic Plains, South Asia
ILRI	International Livestock Research Institute (Nairobi, Kenya)
LGP	Lower Gangetic Plains (subregion of the IGP, including the downstream plains in eastern India [West Bengal], Ganges basin)
MGP	Middle Gangetic Plains (subregion of the IGP, including the midstream plains in eastern India [Eastern UP and Bihar], Ganges basin)
MSP	minimum support price
mt	metric tons
n	number of observations
NCA	net cropped area
ns	nonsignificant
p	probability
PAU	Punjab Agricultural University
RCTs	resource-conserving technologies
R&D	research and development
RWC	Rice-Wheat Consortium of the Indo-Gangetic Plains (New Delhi, India)
sd	standard deviation
SLP	CGIAR Systemwide Livestock Programme
USAID	United States Agency for International Development
TGP	Trans-Gangetic Plains (subregion of the IGP, including the plains in Northwestern India [Punjab, Haryana], straddling the Ganges and Indus basins)
UGP	Upper Gangetic Plains (subregion of the IGP, including the upstream plains in north-central India [the Western UP], Ganges basin)
UP	Uttar Pradesh
ZT	zero tillage

Executive Summary

The research and development community faces the challenge of sustaining crop productivity gains, improving rural livelihoods, and securing environmental sustainability in the Indo-Gangetic Plains (IGP). This calls for a better understanding of farming systems and of rural livelihoods, particularly with the advent of, and strong advocacy for, conservation farming and resource-conserving technologies. This report presents a regional synthesis of four scoping studies to assess crop-livestock interactions and rural livelihoods in each of the four subregions of the Indian IGP: the Trans-Gangetic Plains (TGP: Punjab and Haryana), the Gangetic Plains of Uttar Pradesh (UP), Bihar, and West Bengal. The scoping studies draw from village surveys in three districts per subregion and from secondary data.

The IGP can be divided broadly into eastern and western subregions. The eastern subregion (Eastern UP, Bihar, West Bengal) has problems of poor water control and flooding; rain-fed (monsoonal/kharif) lowland rice is the traditional cereal staple and the mainstay of food security. It was only in recent decades that wheat and other cool-season crops were introduced on a large scale in Eastern India, north of the Tropic of Cancer. In contrast, the western subregion (TGP, Western Uttar Pradesh) is mainly semiarid and would be water-scarce if not for its irrigation infrastructure of canals and groundwater tube wells. In the western plains, winter/rabi wheat has traditionally been, and continues to be, the mainstay of food security. In recent decades, there has been a major increase in the area of rice grown in the monsoonal/kharif season. Another important contrast is that whereas in the Eastern IGP cattle are the predominant livestock, in the Western IGP buffalo dominate. In broad terms therefore, the Eastern IGP is characterized by rural livelihoods based on rice-cattle farming systems, while rural livelihoods in the Western IGP are based on wheat-buffalo farming systems. Therefore, although the IGP is a contiguous plain area, there are significant gradients and variations between subregions. The sheer size of the IGP also implies that each subregion assumes national prominence: the TGP is India's granary; UP is India's most populous state; Bihar is one of India's poorest states and West Bengal is India's most densely populated state.

Livelihood Platforms

The aggregate asset base is markedly more favorable in the Northwest (NW) IGP and declines proceeding to the eastern plains of Bihar. Particularly marked are the larger farm size, larger herd size, and more widespread mechanization and irrigation in the northwest. In contrast, rainfall and population density increase proceeding towards the Eastern IGP, as does the incidence of poverty.

The west-east asset gradient in the IGP also had pronounced effects on factor prices, such as the value of land and labor, both being markedly higher in the NW IGP. Daily wage rates declined from a high in the TGP clusters (Rs 87) to a low in the West Bengal clusters (Rs 39). In contrast, the cost of capital is markedly lower in the NW IGP and increases proceeding eastward. The average monthly interest rates in the informal credit market thereby increased from a low of 1.9% in the TGP to 8.2% in West Bengal. The institutional environment also tends to be more favorable in the NW IGP. Women's role in agriculture increases proceeding eastward. Gender inequity still plays a key role, reflected inter alia by gendered wage rates and lower female literacy.

The diverging agricultural history of the IGP subregions has led to significant variations in terms of poverty alleviation and agricultural productivity. Notwithstanding the ongoing adaptations in cropping and livestock practices, a striking feature of the surveyed communities across the IGP is their apparent current stagnation. Many communities thereby gave a sense that they were waiting to be helped, exhibiting a strong dependence on hoped-for government intervention and demonstrating a lack of personal initiative. Another striking feature of the

communities surveyed across the IGP was the lack of significant shocks having widespread impact on the rural population.

Livelihood Strategies

Livelihood strategies in the surveyed communities predominantly revolved around crop-livestock systems and agricultural labor throughout the IGP, but with significant west-east gradients. Wheat is the dominant food/feed crop in the NW IGP whereas rice is dominant in the eastern plains. Rice-wheat thereby prevails as the dominant cropping pattern in the northwest, whereas proceeding eastward, cropping systems become more diversified. Cereal production in the northwest plains is also more market-oriented, reflecting a larger surplus. The TGP devotes a significant share of the seasonal cultivated area to fodder crops (10%), but the area declines proceeding towards the eastern plains.

Livestock ownership is widespread and complements the rice- and wheat- based cropping systems as the basis of rural livelihoods. The aggregate livestock herd varied from a high of 4.6 cow equivalents per household in the TGP clusters to a low of 1.5 in Bihar. This herd size thereby shows a striking inverse relationship with the prevailing poverty levels reported in the secondary data. Buffalo are the prevailing livestock type in the northwest and show a marked decline proceeding downstream along the Ganges. Ownership of *desi* (local) cows is not widespread, but does show a significant opposite trend. Small ruminants were relatively absent in the northwest but became more prominent moving eastward. Backyard poultry is relatively absent in the upstream IGP subregions, but becomes strikingly common in West Bengal.

Throuhout the IGP, crop production appeared as the main livelihood source for landed households, with livestock typically complementary to, and to a large extent dependent on, the crop enterprise. Landless households depend primarily on their labor asset, with livestock providing an important contribution. There is a marked gradient in the reliance on casual labor: contracting casual labor for crop operations is the rule in the northwest but decreases as one proceeds eastward to the Bihar subregion, where small farms and family labor predominate.

Crop-Livestock Interactions

Wheat straw is the preferred ruminant feed in the NW IGP and rice straw in the East, linked to tradition and availability of mechanical threshers for wheat. The preferred cereal straws have scarcity value and are intensively collected, stored and used as the basal animal feed with eventual surpluses traded. Reported prices of wheat straw in the northern plains average Rs 1.4/kg while those in the eastern plains average Rs 0.8/kg. Stubble-grazing shows a marked west-east gradient in grazing in the IGP, from low levels in the TGP to high levels in the eastern plains. The practice of in-situ burning of crop residues is markedly concentrated in the NW IGP.

Livestoc are generally stall-fed throughout the year. The basal diet consists primarily of cereal straw year-round, supplemented with green fodder, grazing, collected grasses/forage, other crop byproducts, and compound feed. The use of green fodder shows a marked decline along a west-east gradient in the IGP, whereas grazing and collected grasses/forage show a marked increase along the same gradient. Throughout the IGP, milk yields were low and the bovines were not perceived as primary income earners for their owners.

Throughout the IGP, livestock depend on the crop residues with limited reciprocation from the livestock component to the crop component in terms of dung or traction. Crop-livestock integration was most apparent in the West Bengal subregion, with the most pronounced complementarities between crop (rice straw) and livestock production (draft, manure). Crop and livestock components do imply complementary labor needs and internal nonmonetary services at the household level.

Based on these findings, the study goes on to explore the effects on livelihood security and environmental sustainability and provides an outlook and agenda for action including action-research needs for the IGP.

Chapter 1 Introduction

The outstanding contribution of agricultural research towards improving the livelihoods of poor farmers in the IGP through the Green Revolution technologies is well documented (Evenson and Gollin 2003; Frankel 1971; Hazell and Ramasamy 1991; Lipton and Longhurst 1989; Pinstrup-Andersen and Hazell 1985; Rosegrant and Hazell 2001). From the 1960s to the 1980s, cereal production was much improved with the planting of high-yielding wheat and rice varieties combined with the application of fertilizer in the irrigated fields of the IGP. As a result, India moved from a state of deficiency in the staple grains, wheat and rice, to a position of secure self-sufficiency. Now, in the face of diminishing groundwater supplies and degrading soils (Kumar et al. 1999; Pingali and Shah 1999), the challenge is to sustain crop productivity gains, while supporting the millions of families in the IGP—most of whom are resource-poor—to diversify their farming systems in order to secure and improve their livelihoods.

Central to this challenge of ensuring improved livelihoods and environmental sustainability is the ruminant livestock—particularly, buffalo, cattle and goats—which are an integral part of the IGP's farming systems. For decades, beneficial interactions between rice and wheat cropping and ruminant livestock have underpinned the livelihood systems of the IGP. Yet, until recently, there has been little systematic research to assess the benefits of these interactions, or to evaluate the potential for improvement. Based on a review of over 3,000 papers from South Asia, Devendra et al. (2000) reported a paucity of research that incorporates livestock interactively with cropping, and a woeful neglect of social, economic and policy issues. Biophysical commodity-based crop or livestock research dominated, a systems perspective was lacking, and many of the developed technologies were not adopted. More recently, broad classifications of crop-livestock systems in South Asia and their component technologies have been documented (Paris 2002; Parthasarathy Rao et al. 2004; Parthasarathy Rao and Hall 2003; Thomas et al. 2002). However, it is clear that a better understanding of farming systems and of the livelihood objectives of landed and landless families, including the way they exploit crop-livestock interactions, will be required if we are to be successful in improving rural livelihoods and securing environmental sustainability in the IGP.

Taking a systems approach and applying a livelihoods perspective (Ellis 2000) are particularly important because of the dynamics and diversity of the IGP's social geography, its agriculture and the complexity of its crop-livestock interactions. Current understanding of the interactions is only partial; hence the need to update our knowledge and to assess the implications for agricultural research and development (R&D)—particularly with the advent of, and strong advocacy for, conservation agriculture and resource-conserving technologies (RCTs, e.g., zero tillage, permanent beds, mulching). The RCTs are having some success in improving resource use efficiency for crop production (RWC 2005; Singh et al. 2005), but there is a lack of information about their impacts on overall farm productivity and its livestock components (Seth et al. 2003). Improving our understanding of crop-livestock interactions and their contributions to rural livelihoods will better position the R&D community to be more effective in addressing the major challenges of improving livelihoods while ensuring environmental sustainability.

It was against this background that the RWC designed a scoping study with the following objectives:

- To assess rural livelihoods and crop-livestock interactions in the IGP.
- To understand the spatial and seasonal diversity and dynamics of livelihoods and crop-livestock interactions, particularly in terms of the underlying drivers and modifiers.
- To assess the corresponding implications for R&D programs.

The study was carried out across the IGP of India, comprising the states of Punjab, Haryana, Uttar Pradesh (UP), Bihar, and West Bengal. For purposes of this study we grouped the Indian IGP into four

subregions: the Trans-Gangetic Plains (TGP: Punjab and Haryana) and the Gangetic Plains of UP, Bihar and West Bengal. The Gangetic Plains of UP thereby comprise the Upper Gangetic Plains and part of the Middle Gangetic Plains; Bihar comprises most of the Middle Gangetic Plains and West Bengal the Lower Gangetic Plains (Figure 1). For each subregion the study results have been compiled in a separate report (TGP - Erenstein et al. 2007c; UP - Singh et al. 2007; Bihar - Thorpe et al. 2007; and West Bengal - Varma et al. 2007). The present report presents a regional analysis and synthesizes the outcomes of the four studies.

The study reports are structured as follows. Chapter 2 presents the overall methodology followed and details of the specific survey locations. Chapter 3 presents the study area drawing primarily from secondary data and available literature. Chapter 4 analyzes the livelihood platforms in the surveyed communities, distinguishing between the livelihood assets, access modifiers and trends and shocks. Chapter 5 describes the livelihood strategies in the surveyed communities, with particular attention to crop and livestock production. Chapter 6 assesses the crop-livestock interactions in the surveyed communities, with particular emphasis on crop-residue management and livestock-feeding practices. Chapter 7 first discusses the effects on livelihood security and environmental sustainability and subsequently dwells on the outlook for the surveyed communities and draws together an agenda for action.

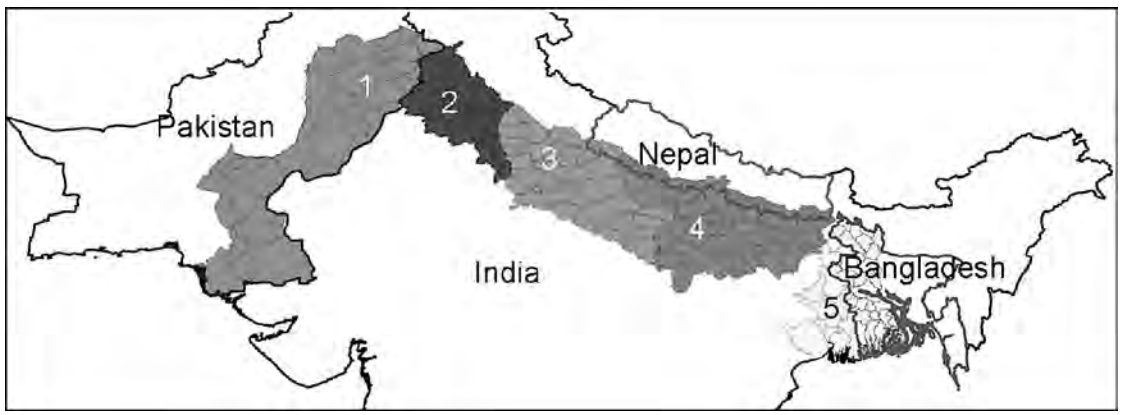

Figure 1. The Indo-Gangetic Plains with the five subregions.
Notes: 1: Indus Plains; 2: Trans-Gangetic Plains [TGP]; 3: Upper Gangetic Plains [UGP]; 4: Middle Gangetic Plains [MGP]; 5: Lower Gangetic Plains [LGP].

Chapter 2 Methodology

Conceptual Framework

The scoping study set out to assess rural livelihoods and crop-livestock interactions in the Indo-Gangetic Plains (IGP) through the combined use of secondary information and village-level surveys. In order to better dissect and understand livelihoods and the contributions of crops, livestock and interactions of the sample village communities, the scoping study took as its analytical framework the "assets-mediating processes-activities" model presented by Ellis (2000, Figure 2).

The framework provides a systematic way of (i) evaluating the assets of households and communities and the factors (e.g., social relations or droughts) that modify access to these assets; (ii) describing and understanding current livelihood strategies; and then (iii) exploring the options for reducing poverty and addressing issues of sustainability. We took particular interest in our scoping study to understand the dynamics of the livelihood systems and how these influenced decisions on the management of rice-wheat cropping and of livestock and their interactions, e.g., the trade-offs between resource-conservation technologies (RCTs) and the use of crop residues to feed buffalo for milk production. Taking this livelihoods approach ensured that natural resource-based and other activities were addressed and that their effects on livelihood security and environmental sustainability were assessed.

Figure 3 schematically presents the linkages between crop and livestock systems in the IGP that further guided the study. The scoping study did not intend a comprehensive assessment of the crop and livestock subsectors of India's IGP. Instead, emphasis was on the linkages—the crop-livestock interactions—at the farm and village level between the two subsectors. The study therefore focused on the dynamics at the interface of the crop and livestock subsectors. Within that dynamics a further focus was the management of crop residues because of their importance as ruminant livestock feeds and their role in natural resources management.

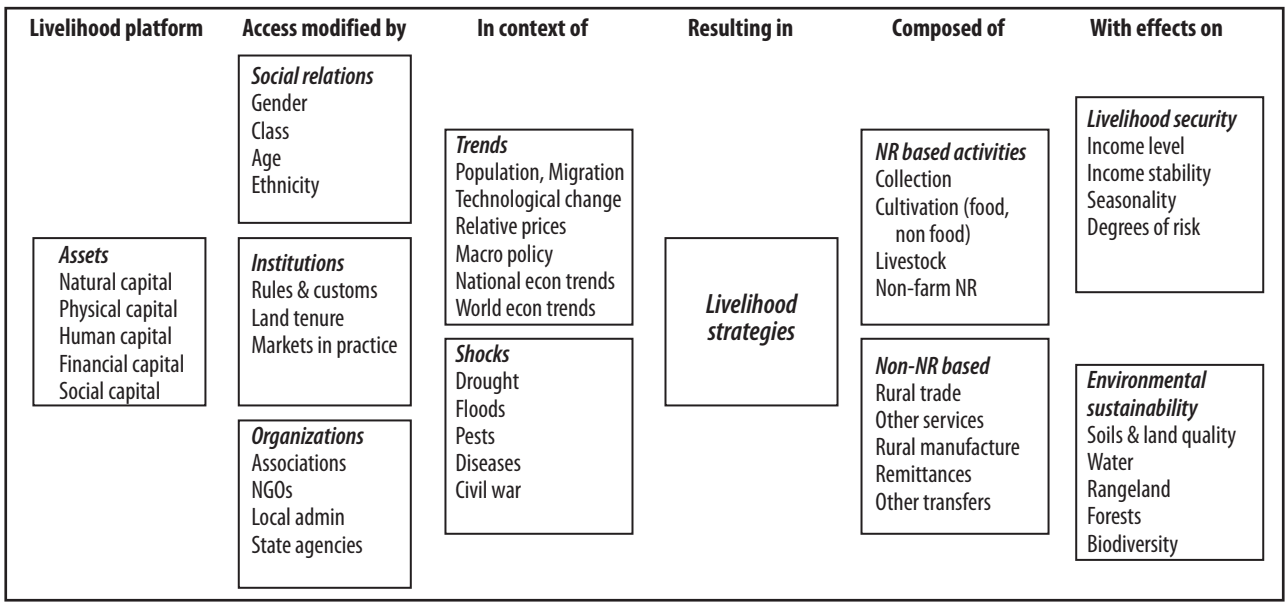

Figure 2. A framework for the analysis of rural livelihoods.
Source: Ellis 2000.

Village-Level Survey

The main data source for the scoping study was a village-level survey of 72 communities from April to June 2005. The communities were randomly selected using a stratified cluster approach. At the first level, we grouped the Indian IGP into four subregions: the Trans-Gangetic Plains (TGP: Punjab and Haryana) and the Gangetic Plains of UP, Bihar and West Bengal. Each subregion comprises various agro-ecological subzones as described in the classification by Narang and Virmani (2001, Figure 4) and Kumar et al. (2002). At the second level, we purposively selected a representative district from each of the three main IGP agro-ecological subzones within the subregions. These locations were selected to reflect the range of agro-ecological conditions in the IGP and to capture the expected variation in farming systems, including level of access to irrigation services. At the third and final cluster level, we randomly selected six villages around a central point, typically the district headquarters (Figure 5). The villages were randomly selected by taking two villages along three opposing directions, one village typically relatively close to the road (generally within 5 km) and the second further away (generally more than 15 km). Table 1 shows the district and agro-ecological classification of each cluster of surveyed villages in the IGP. Each cluster thus comprises six villages, with three clusters representing different agro-ecological subzones for each IGP subregion (i.e., 18 villages per subregion) and a total of four subregions (i.e., a total of 72 villages).

Within each village we interacted with self-selected groups of key informants. We thereby attempted to include a representative range of village stakeholders during a half-day village visit, covering the diverse spectra of gender, social and wealth categories (including landed and landless).

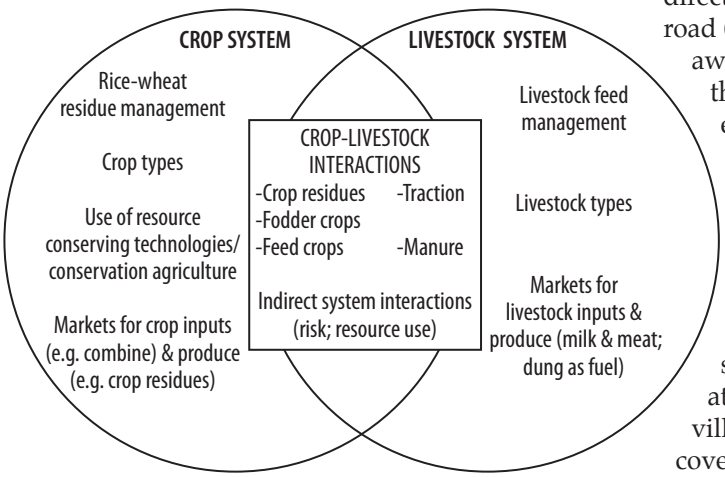

Figure 3. A schematic representation of crop-livestock interactions in the Indo-Gangetic Plains.

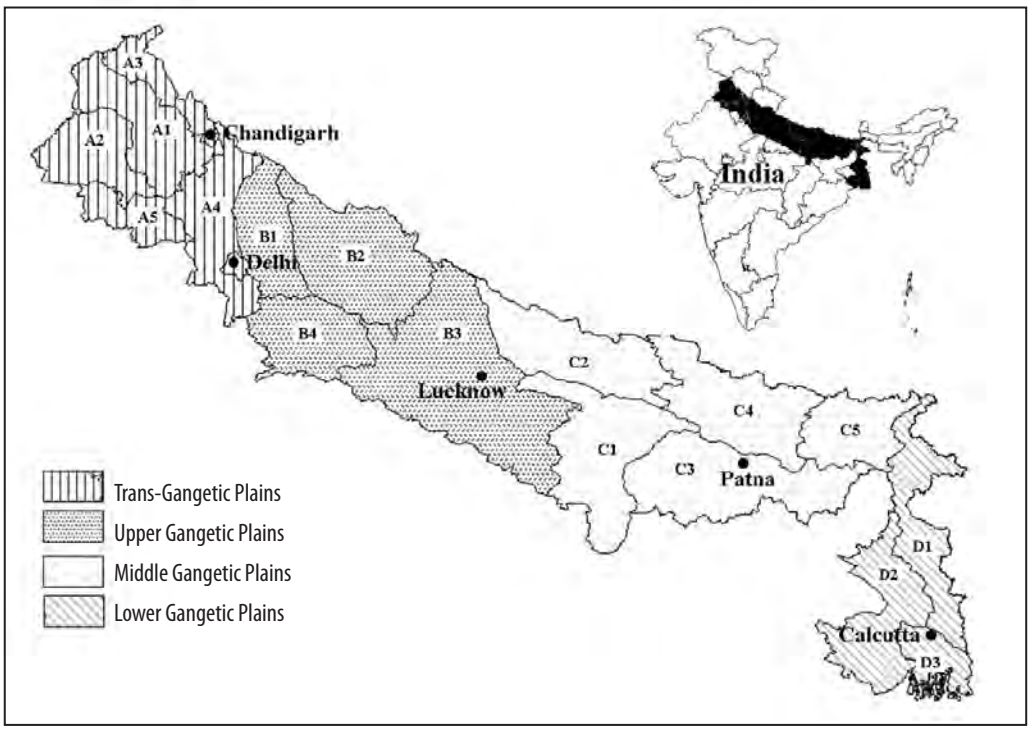

Figure 4. Subregions and agro-ecological subzones of the Indo-Gangetic Plains.
Source: Adapted from Narang and Virmani 2001.

This half-day visit typically included a briefing with key informants of the village, a larger group meeting with villagers (mainly landed), a separate smaller group meeting with landless, and a visual survey by walking through and around the village. The separate meeting with the landless was deemed necessary to enable their more active participation.

However, we were less successful in involving women who were virtually excluded from the group discussions (Table 2). In part, this was dictated by the prevailing social norms and definitely not aided by the male-biased team composition. Team members were thereby requested to be assertive and pay particular attention to gender issues in an attempt to readdress the imbalance.

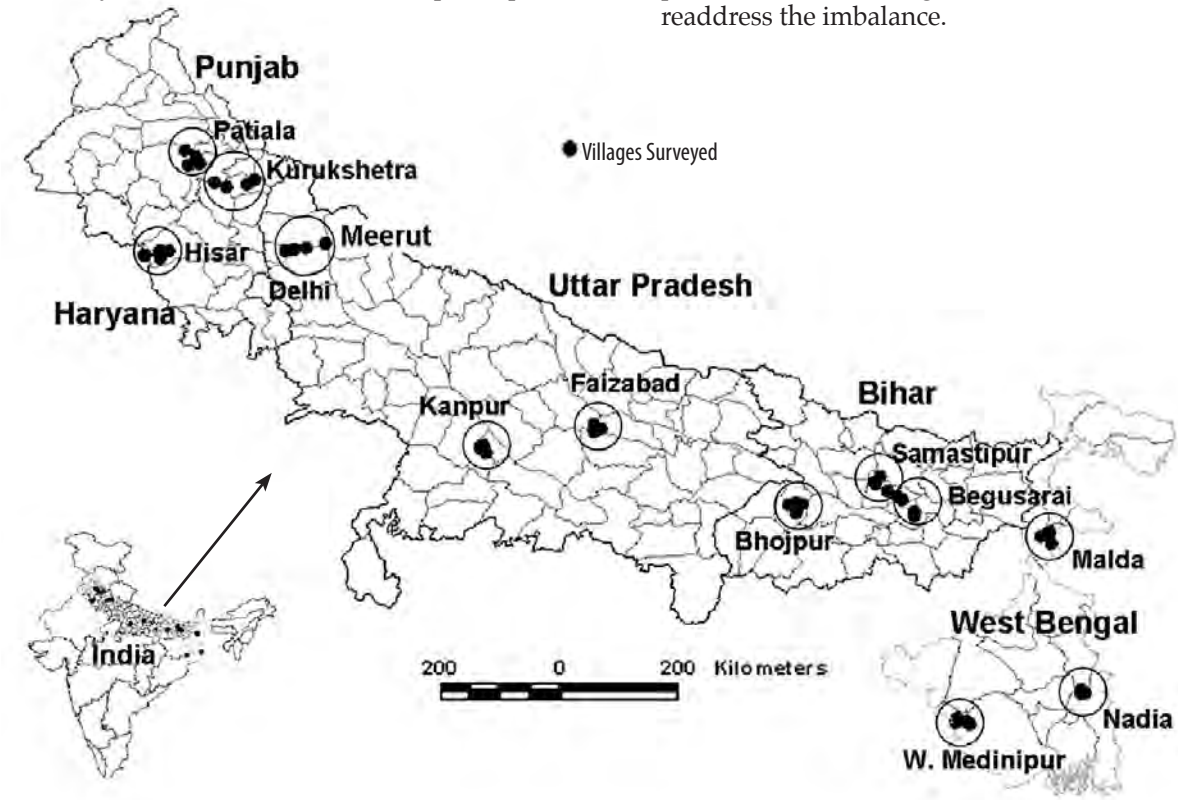

Figure 5. Location of the 12 clusters of surveyed villages within the Indo-Gangetic Plains.

Table 1. Names and zones of the 12 surveyed village clusters in the Indo-Gangetic Plains.

State	Punjab/Haryana	Uttar Pradesh	Bihar	West Bengal
Cluster (zone)	Patiala (Central-Plains zone, A_1)	Meerut (Western Plains, B_1)	Bhojpur (South Bihar Plains, C_3)	Malda (Barind Plains D_1)
	Kurukshetra (Eastern zone, A_4)	Kanpur (Central Plains, B_3)	Samastipur (Northwest Plains, C_4)	Nadia (Central Alluvial Plains—old and new alluvial zone, D_1)
	Hisar (Western zone, A_5)	Faizabad (Eastern Plains, C_1)	Begusarai (Northeast Plains, C_5)	West Medinipur (Central Alluvial Plains—Laterite and red-soil zone, D_2)

Notes: In between brackets are the name and code of the agro-ecological subzone combining Narang and Virmani 2001:6 and Kumar et al. 2002:22.
Figure 4 maps the coded subzones.

Table 2. Median number and gender of participants in the village-group discussions in each subregion (18 villages per subregion) in the Indo-Gangetic Plains.

	Village group discussion		Landless group discussion	
Subregion	No. of participants	No. of female participants	No. of participants	No. of female participants
Punjab/Haryana	11	0	5	0
Uttar Pradesh	6	0	2	0
Bihar	20	0	8	0
West Bengal	20	0	10	5

The village survey used semi-structured interviews using a survey instrument (see individual subregion reports, e.g., Erenstein et al. 2007c; Annex 4). A village leader was generally first asked to provide quantitative descriptors of the village (people, resources, infrastructure). Then group discussions described the crop and livestock subsystems practiced in the village and other significant aspects of village livelihoods. Particular attention was given to the management of crop residues and to livestock-feed resources. Data were collected on the expected drivers of crop-livestock interactions, like the cost of daily-hired labor and the level of access to irrigation.

At each stage of the survey process, respondents were asked to identify and discuss the critical issues that affected their living standards and the constraints to, and the opportunities for, improving their livelihoods and those of the village. In this way, the discussions attempted to provide a sound understanding of the opinions and perspectives of each village community and of its major social groupings regarding policy issues and policy making, i.e., to gain a 'user' or bottom-up perspective and to avoid being prescriptive.

At each location within each region, three teams completed the survey instrument for two villages within a day. Members of a core team participated in the surveys in each of the four regions and in each of the three locations which constituted the subregion of each region. This gave continuity and consistency of research approach and ensured that the core team members absorbed and analyzed the survey and related information from the village studies across the Indian IGP from Punjab in the northwest to West Bengal in the east (Figure 1). Within each survey team at each cluster, the core members were joined by staff from the local Krishi Vigyan Kendra (Extension Outreach Program, India) or other State Agricultural University Departments and/or their counterparts in the Departments of Agriculture and Animal Husbandry of the State Government (see individual subregional reports for actual participants, e.g., Erenstein et al. 2007c, Annex 3).

Analysis and Integration of the Information

The quantitative primary data from the village surveys were summarized using descriptive statistics. These results were complemented by the information and statistics gathered from secondary sources. The descriptive statistics not only helped gain a better understanding of the type and extent of crop-livestock interactions within each subregion but also showed the variation within and across the four major regions. The descriptive statistics were also useful in examining informal hypotheses about the possible drivers of interactions between crops and livestock and in helping to identify the key modifiers of the effects of the drivers.

It should be noted that the nature of the survey method of collecting data dictated that each quantitative observation (e.g., area of irrigated land in the village or the number of buffalo) was a guesstimate from a respondent or a group of respondents. As such, estimates of variables (e.g., mean number of buffalo for the TGP subregion sample of villages) calculated from these guesstimates are indicative, not definitive, results and are therefore presented in the results section at an appropriate level of rounding (e.g., village population to the nearest 100).

The nature of the data and study also implies that the analysis is mainly descriptive. All the tables in the present report refer to village-level survey data unless otherwise mentioned. The tables typically present unweighted averages across surveyed villages, i.e., the average of the 18 surveyed villages in the case of the subregions and of the 72 villages in the case of the overall mean. This applies to both absolute and relative values (i.e., in the case of % of households the % was estimated at the village level and subsequently averaged across villages). These tables also present measures of variability and the significance of differences between the surveyed subregions.

The livelihood framework can be applied at different scales. Our focus here is on the village and household levels. At the latter level, we will often distinguish between farm households (with land access and crop-production activities), landless households (no access to agricultural land [owned or rented] or crop production activities) and village households (includes both farm and landless). Finally, in applying the livelihood framework in this study, we use the principle of 'optimal ignorance,' seeking out what is necessary to know in order for informed action to proceed (Scoones as cited in Ellis 2000:47).

It is important to remember that a scoping study, by its very nature, is not designed to provide definitive answers, but rather to flag issues for subsequent in-depth research. Therefore, the emphasis of the study methods was learning through drawing on available information and current knowledge from secondary sources and from the village surveys, interpreting and synthesizing the data from these sources and finally identifying gaps both in the information and our knowledge and in its application.

Chapter 3 Study Area

The IGP (Figure 1) can be divided broadly into eastern and western subregions. The eastern subregion has problems of poor water control and flooding; rain-fed (monsoonal/kharif) lowland rice is the traditional cereal staple and the mainstay of food security. It was only in recent decades that wheat and other cool-season crops were introduced on a large scale in the northeast of the Tropic of Cancer. In contrast, the western subregion is mainly semiarid and would be water-scarce if not for an excellent irrigation infrastructure of canals and groundwater tube wells. In the western plains winter/rabi wheat has traditionally been, and continues to be, the mainstay of food security, aided by good winter rains (100–110 mm) and low temperatures appropriate for vernalization and good grain setting in wheat (Narang and Virmani 2001). In recent decades, there has been a major increase in the area of rice grown in the monsoonal/kharif season. Another important contrast is that whereas in the Eastern IGP cattle are the predominant livestock, in the Western IGP, buffalo dominate. In broad terms therefore the Eastern IGP is characterized by rural livelihoods based on rice-cattle farming systems, while rural livelihoods in the Western IGP are based on wheat-buffalo farming systems.

Therefore, although the IGP is a contiguous plain area, there are significant gradients and variations between subregions. For the present study, we have subdivided the Indian IGP into four major subregions: the TGP (Punjab and Haryana) and the Gangetic Plains of Uttar Pradesh, Bihar, and West Bengal (Figure 1).

Widespread irrigation and the Green Revolution have transformed the semiarid TGP into India's granary, producing 21% of the nation's food grains on only 3% of its area. The subregion is characterized by rural livelihoods based on wheat-buffalo farming systems. Over the last 30 years, there has been widespread adoption of rice, making rice-wheat the predominant cropping system (35% of the system area in the IGP). Farm size is relatively large and the area has witnessed a rapid mechanization. Buffalo (dairy) increasingly dominate the bovine population, making the TGP the most densely buffalo-populated area of India. There has been a sharp decline in draft animals and small ruminants and, in Punjab, in poultry. The agricultural growth was accompanied by steady reductions in poverty, resulting in the lowest rural poverty rates in India (6.4–8.3%). Punjab and Haryana are the prime beneficiaries of the Minimum Support Price (MSP) schemes for rice and wheat, removing market risk from these crops. Biophysical consequences, however, are the declining groundwater table and the degrading of soils, contributing to a slowdown in agricultural growth in the 1990s (for further details see Erenstein et al. 2007c).

Uttar Pradesh is India's most populous state. Nearly a third (31%) of the rural population is below the poverty line, with poverty concentrated rurally, socially and spatially in the Eastern UP. Uttar Pradesh eloquently illustrates the transition from rural livelihoods based on buffalo-wheat in the West to cattle-rice in the East. As in the neighboring TGP, the Western Uttar Pradesh has benefited from widespread irrigation development and the Green Revolution. Uttar Pradesh is a major producer of wheat, rice and sugarcane. Uttar Pradesh alone constitutes nearly half the rice-wheat area in the IGP. Farm size is relatively small, reflecting its high rural population density. The agricultural growth of UP was accompanied by steady reductions in poverty between the late 1970s and 1980s but economic growth faltered in the 1990s (for further details see Singh et al. 2007).

Bihar is one of India's poorest states: 44% of the rural population is below the poverty line. Bihar is characterized by diverse rural livelihoods based on rice-cattle farming systems in a risk-prone and underdeveloped environment. Wheat is a nontraditional crop in Bihar but over the last decades it has become a major crop and rice-wheat a major cropping system (17% of the system area in the IGP). Farm size is small whereas half the population is landless, reflecting its high rural population density and population growth (for further details see Thorpe et al. 2007).

West Bengal is India's most densely populated state and is characterized by rural livelihoods based on rice-cattle farming systems. Nearly a third (32%) of the rural population is below the poverty line, with poverty concentrated rurally and socially. The formerly food-deficit state has had a significant spurt in agricultural production from the early 1980s and is now surplus in food grain. Intensification (particularly *boro* rice) and diversification (vegetables, particularly potato) were the main pathways for agricultural growth, aided by the advent of shallow tube-well irrigation. Rice-wheat systems are relatively limited (<3% of system area in the IGP). West Bengal is the most densely stocked state of India in terms of cattle, small ruminants and poultry. Equity and growth have benefited from the state's emphasis on land reform and decentralization through people's participation in Panchayat institutions. Agricultural growth slowed down significantly in the 1990s in combination with an overall slowdown in aggregate rural employment (for further details see Varma et al. 2007).

Secondary data highlight some of the biophysical gradients and variations between these four subregions of the Indian IGP (**Annex** 1**)**. The west-east rainfall gradient along the IGP is particularly striking (Table 3), with an annual rainfall of 619 mm per annum in Haryana (TGP) in the northwest increasing to more than double (1,462 mm per annum) in the lower West Bengal Plains in the east. Despite this marked gradient, the rainfall remains markedly concentrated during the northwest monsoon (76%– 88% of annual rainfall). Conversely, and inversely associated with the rainfall gradient, there is a marked irrigation gradient, with 95% of Punjab being irrigated, declining to only 43.5% in West Bengal (**Annex** 1). These agro-ecological gradients help explain some of the marked variations in cropping patterns and productivity across the IGP states (**Annex** 2).

The secondary data also illustrate some of the socioeconomic gradients and variations between these four subregions of the Indian IGP (**Annex** 1). This was to be expected for an area with an aggregate population of 375 million (36% of the total in India) living on a geographical area of 518,000 km^2 (16% of the total in India), including some of India's most densely populated states. Table 4 presents selected district-level indicators in relation to the Millennium Development Goals (MDGs) for the four IGP subregions distinguished. The table does so both in terms of all districts in each subregion and in the surveyed districts only. For both subsets the table highlights the statistical significance of observed differences. Table 5 presents some additional socioeconomic indicators in the same way, and flags some equity and gender issues. A number of observations can be drawn from these two tables. First, the poverty indicator reiterates the marked poverty of Bihar as against the relatively low incidence of poverty in the TGP, with intermediate levels in Uttar Pradesh and West Bengal. Second, overall, the various indicators show a similar pattern, whereby Bihar typically scores as the least favorable, followed in increasing order by Uttar Pradesh, West Bengal and the TGP. There are some marked exceptions. West Bengal shows a markedly high incidence of hunger. The sex ratio shows a marked west-east gradient, with the least favorable ratio in the TGP—reflecting the female infanticide problem. Third, the surveyed districts approximate the overall average of each subregion, suggesting the surveyed districts are relatively representative. Similarly, the variations between the subsets of surveyed districts generally mirror those variations between all districts in each subregion.

The biophysical and socioeconomic gradients and variations have a marked influence on rural livelihood platforms. Erenstein et al. (2007b) have illustrated the spatial variation in livelihood assets and its association with poverty across the Indian IGP. In the subsequent chapters, we will illustrate how the asset base varies over the surveyed communities and how these variations have shaped rural livelihood strategies and crop-livestock interactions.

Table 3. Season-wise distribution of normal rainfall.

Subdivision	Pre-monsoon (March–May)	Southwest monsoon (June–Sept.)	Post- monsoon (Oct.–Dec.)	Winter Months. (Jan.–Feb.)	Total (mm)
Punjab	54	507	41	52	654
Haryana	36	515	30	38	619
Western Uttar Pradesh	29	760	49	35	873
Eastern Uttar Pradesh	29	899	60	28	1,016
Bihar	75	1,007	77	28	1,187
Gangetic West Bengal	171	1,111	149	31	1,462

Source: IASRI 2005:17.

Table 4. Selected Millennium Development Goals-related development indicators at the district level.

	Population below the poverty line (%)	Households going hungry (%)	Infant mortality rate (per 1,000 births)	Children getting complete immunization (%)	Literacy rate (%)	Gross enrolment ratio (elementary level, %)
Average all districts[1] [n=161]						
- Punjab/Haryana	8.3 a	0.8 a	64.3 b	70.6 d	69.0 c	72.1 b
- Uttar Pradesh	29.7 b	1.8 a	89.1 d	42.6 b	57.4 b	51.3 a
- Bihar	41.2 c	3.3 b	70.4 c	19.7 a	46.9 a	55.0 a
- West Bengal	31.7 b	9.7 c	56.0 a	53.3 c	66.7 c	83.1 c
p	0.00	0.00	0.00	0.00	0.00	0.00
Average surveyed districts[1] [n=72]						
-Punjab/ Haryana	7.2 a	2.3 a	67.7 ab	73.5 c	68.6	65.9
- Uttar Pradesh	30.3 b	2.4 a	92.0 c	39.7 b	63.4	70.4
- Bihar	54.9 c	1.4 a	71.7 b	16.1 a	51.4	59.7
- West Bengal	32.3 b	12.7 b	61.3 a	51.3 b	64.2	83.8
p	0.01	0.06	0.00	0.00	0.11	ns

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison by block. ns: nonsignificant.

[1] Unweighted average across districts.

Source: Derived from Debroy and Bhandari 2003.

Table 5. Selected additional socioeconomic indicators at the district level.

	0–6 sex ratio (females per 1,000 males)	% of 0–6-year olds in the population	Female: male literacy ratio (%)	Pupil teacher ratio	Female work participation (%)	% of women receiving skilled attention during pregnancy
Average all districts[1] [n=161]						
- Punjab/Haryana	804 a	26.0 a	77.2 c	52.6 b	20.2 c	67.9 d
- Uttar Pradesh	914 b	35.0 c	60.6 b	44.6 a	13.0 a	30.2 b
- Bihar	938 c	37.8 d	54.5 a	69.7 c	16.7 b	22.1 a
- West Bengal	963 d	27.9 b	75.3 c	78.4 d	16.1 b	53.4 c
p	0.00	0.00	0.00	0.00	0.00	0.00
Average surveyed districts[1] [n=72]						
- Punjab/Haryana	790 a	25.5 a	75.8 b	54.2 a	19.8	71.5
- Uttar Pradesh	902 b	32.4 bc	67.7 b	50.4 a	11.6	43.4
- Bihar	941 bc	37.3 c	58.1 a	79.1 b	13.6	31.4
- West Bengal	965 c	30.0 ab	76.2 b	84.9 b	16.7	54.0
p	0.00	0.03	0.02	0.04	0.19	ns

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison by block. ns: nonsignificant.

[1] Unweighted average across districts.

Source: Derived from Debroy and Bhandari 2003.

Chapter 4 Livelihood Platforms

Livelihood Assets

The starting points of the livelihood framework are the assets owned, controlled, claimed or some other means accessed by the farm households. These are the basic building blocks upon which households are able to undertake production, engage in labor markets, and participate in reciprocal exchanges with other households (Ellis 2000:31). The asset base of the surveyed villages will be reviewed, based on five asset categories: natural capital, physical capital, human capital, financial capital and social capital (Figure 2).

Natural capital

The main natural capital assets utilized by the people to generate means of survival in the surveyed villages comprise land, water and livestock. The IGP landscape is primarily plain, of low altitude and highly suitable for cultivation of crops. The relative 'plainness' of the IGP is illustrated by the significant, yet relatively minor variation in, altitudes between the communities surveyed (Table 6): from a high of 244 m in the Patiala cluster in the upstream TGP to a low of 29 m, thousands of kilometers further downstream in the Nadia cluster in West Bengal. Except for some patches with problem soils (e.g., salinity [salt-rich], sodicity [sodium-rich], waterlogging), the inherent productivity of the land in the surveyed communities is primarily limited by the west-east rainfall gradient and its seasonality, but widely enhanced by irrigation development. This primarily draws from groundwater resources, an issue further elaborated below.

Farm size showed a prominent west-east gradient in the surveyed village clusters, from a high of 3.7 hectares in the TGP to only 0.7 hectare in West Bengal (Table 6). Access to land in the surveyed village clusters showed a west-east division, with more widespread access to land in Uttar Pradesh and TGP, as against only two-thirds of households in both the Bihar and West Bengal clusters (Table 6). These variations reflect the west-east population density gradient and inequitable access to land. Overall, our village findings compare reasonably well with aggregate state-level data (Annex 1).

Livestock constitute an important natural asset both in terms of value and prevalence, and ownership by households is widespread across surveyed communities. The herd size decreases along a west-east gradient from the TGP to Uttar Pradesh to Bihar (Table 6), but regains in size proceeding downstream to West Bengal (at par with Uttar Pradesh). Other natural capital assets are relatively limited in the surveyed communities.

Table 6. Natural capital indicators.

Subregion	Altitude (m)[a]	Access to land (% of households)	Farm size (ha/farm household)	Herd size (no. of cow equivalents/household)[b]
Trans-Gangetic Plains	229 c	72 ab	3.7 c	4.6 c
Uttar Pradesh	161 b	84 b	1.7 b	3.2 b
Bihar	49 a	65 a	1.3 ab	1.5 a
West Bengal	49 a	69 a	0.7 a	2.8 b
Mean (sd, n, p)	118 (88,69,0.00)	73 (21,72,0.06)	1.8 (1.8,72,0.00)	3.0 (2.2,72,0.00)

Notes: sd: standard deviation; n: number of observations; p: significance of group effect. Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

[a] Indicative value from Global Positioning System (GPS).

[b] Using following weights: 1.2 for buffalo, crossbred cows and draft animals; 1 for desi cows and equines; 0.1 for sheep, goats and pigs; and 1.4 for camels.

Physical capital

The TGP-surveyed village clusters had a markedly more developed physical capital asset base—through both public and private investment. These villages typically had a high coverage of services (Table 7), good market access (Table 8) and widespread irrigation development (Table 9) and mechanization (Table 10).

Irrigation development was particularly limited in the West Bengal clusters (Table 9; Varma et al. 2007). There was also significant variation in the type of irrigation development, which has implications for the cost and reliability of irrigation. Canal irrigation was primarily confined to the northwest plains (TGP, the Western Uttar Pradesh) and tends to be relatively cheap (a flat rate per crop season) although also relatively insecure, being dependent on the seasonal operation of canals and field location in the scheme (head or tail). Diesel tube wells are more expensive to run but relatively secure, and show a marked increase along a west-east gradient from the TGP

Table 7. General physical capital indicators.

Subregion	Electricity supply (% of households)	Public water supply (% of households)	No. of phones (no./100 households)	Availability of public transport (% of villages)
Trans-Gangetic Plains	99 c	86 b	33 b	79 b
Uttar Pradesh	55 b	6 a	9 a	42 a
Bihar	23 a	2 a	3 a	39 a
West Bengal	44 b	2 a	7 a	56 ab
Mean	55	24	13	54
(sd, n, p)	(45,72,0.00)	(42,72,0.00)	(19,72,0.00)	(43,72,0.02)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Table 8. Selected market-access indicators.

Subregion	Good access road (% of villages)	Travel time to urban center (minutes)	Travel time to agricultural market (minutes)
Trans-Gangetic Plains	100 b	24 a	25 a
Uttar Pradesh	50 a	33 ab	49 b
Bihar	50 a	36 bc	34 ab
West Bengal	59 a	48 c	34 ab
Mean	65	35	36
(sd, n, p)	(48,71,0.00)	(23,70,0.01)	(28,68,0.08)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Table 9. Irrigation indicators.

Subregion	Area irrigated (%)	Primary irrigation source (% of villages, n=69)			
		Electric tube well	Diesel tube well	Canal	Pumped from surface water
Trans-Gangetic Plains	87 b	61	11	33	0
Uttar Pradesh	76 b	22	72	6	0
Bihar	80 b	0	100	0	0
West Bengal	56 a	47	40	0	13
Mean	74	32	57	10	3
(sd, n, p)	(32,72,0.02)				

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Table 10. Mechanization indicators.

Subregion	No. of tractors (per 100 farm households)	No. of power tillers (per 100 farm households)	No. of combines (per 100 farm households)	No. of zero-tillage drills (per 100 farm households)
Trans-Gangetic Plains	31 c	0.0	1.4 b	2.9 b
Uttar Pradesh	10 b	0.0	0.0 a	0.0 a
Bihar	2 a	0.0	0.0 a	0.0 a
West Bengal	2 a	1.3	0.0 a	0.0 a
Mean	11	0.3	0.3	0.7
(sd, n, p.)	(17,72,0.00)	(2.0,72,0.13)	(1.2,72,0.00)	(2.7,72,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

to Bihar. Electric tube wells take an intermediate position: drawing on subsidized electricity rates (World Bank 2005) but subject to an erratic rural electricity supply. Electric tube wells show a marked decrease along a west-east gradient from the TGP to Bihar, mirroring the decrease in rural electrification. Electric tube wells are also the main irrigation source in the West Bengal clusters, although overall irrigation development is more limited.

The mechanization gradient over the surveyed clusters is also particularly striking (Table 10) and allows for three main conclusions. First, the TGP stands out with significantly higher numbers of large-scale mechanization: tractors, combiners and tractor-drawn zero-till drills. Second, in terms of tractors, there is a marked west-east gradient from a high in TGP to Uttar Pradesh to Bihar/West Bengal. Third, small-scale power-tillers (2-wheel tractors) are markedly concentrated in West Bengal, with about an equal number as (4-wheel) tractors in the surveyed communities.

Human capital

The most marked variation in human capital over the surveyed village clusters was the village-level population density. This showed a marked west-east division, with Bihar and West Bengal densities at more than double those reported for TGP and Uttar Pradesh (Table 11). Particularly the densities of Bihar and West Bengal imply a significant surplus in rural labor relative to land and significant pressure on the overall natural resource base. The village-level densities reiterate the significant gradient of population density observed in the secondary data, albeit our levels being more extreme for the eastern sector. The Bihar clusters also reported the highest average family size (Table 11). Over a third of the household heads in the surveyed villages had no formal education, which may be assumed as synonymous with illiteracy. Contrary to the secondary data which typically show less-favorable literacy for UP and particularly Bihar (Table 4; **Annex** 1), there was no significant variation over the four subregions (Table 11).

Financial and social capital

Specific indicators for financial and social capital were not collected, but from the village discussions it became clear that they played an important and varied role that merits closer attention in future studies. The increasing importance of small ruminants moving in the eastern plains may reflect their role as a reserve of financial capital that is more easily divisible than a cow or a buffalo in households with scarce financial capital. On average, the surveyed communities comprised 2,700 persons and 370 households per village (Table 12), providing a rough indicator of social coherence. Surveyed villages in Bihar had the largest population, reflecting the tendency to have more households and larger families per household.

Synthesis

Although agriculture remains the mainstay of rural livelihoods throughout the IGP, there are significant variations in the asset base over subregions. Figure 6 provides a stylized synthesis of some of the major observed gradients in the asset base over the surveyed villages. In terms of the subregions surveyed, the NW IGP comprises the subregion of the Trans-Gangetic Plains (Punjab and Haryana) and the Eastern IGP encompasses the Bihar subregion. The UP subregion illustrates the transition between these extremes with, for instance, NW Uttar Pradesh (the Meerut cluster) being closely associated with the NW IGP category. The West Bengal subregion takes a somewhat mixed position, whereby some

Table 11. Human capital indicators.

Subregion	Village-level population density (no. of persons/km^2)	Family size (no./ household)	Household head with no formal education (% of households)
Trans-Gangetic Plains	400 a	7.9 ab	32
Uttar Pradesh	800 a	7.7 ab	41
Bihar	2,000 b	9.4 b	33
West Bengal	1,700 b	6.5 a	37
Mean	1,200	7.9	36
(sd, n, p)	(1000,71,0.00)	(3.1,72,0.04)	(26,72,ns)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Table 12. Village size.

Subregion	No. of persons	No. of households
Trans-Gangetic Plains	2,300 a	320
Uttar Pradesh	2,600 a	360
Bihar	4,300 b	510
West Bengal	1,700 a	280
Mean	2,700	370
(sd, n, p)	(2400,72,0.00)	(310,72,0.14)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

indicators fall in the Eastern IGP category and some at intermediate levels. Overall, the aggregate asset base is markedly more favorable in the NW IGP and declines as one proceeds towards the eastern plains of Bihar. Particularly marked are the larger farm size, larger herd size, and more widespread mechanization and irrigation in the northwest. In contrast, rainfall and population density increase proceeding to the Eastern IGP, as does the incidence of poverty. This stylized synthesis is primarily for illustrative purposes and reiterates the most significant trends. A more in-depth analysis of the spatial variation and gradients for livelihoods assets across the Indian IGP is provided in Erenstein et al. 2007b.

Access Modifiers

The translation of a set of assets into a livelihood strategy, composed of a portfolio of income-earning activities, is mediated by a large number of contextual, social, economic and policy considerations. The key categories of factors that influence access to assets and their use in the pursuit of viable livelihoods are access modifiers, on the one hand, and the trends and shock factors, on the other (Figure 2). Access modifiers include social relations, institutions and organizations and comprise the social factors that are predominantly endogenous to the social norms and structure. The trends and shock factors consist predominantly of the exogenous factors of economic trends and policies and unforeseen shocks with major consequences on livelihood viability (Ellis 2000:37–8). The access modifiers as pertaining to the study sites are reviewed here, whereas the subsequent section reviews the trends and shocks.

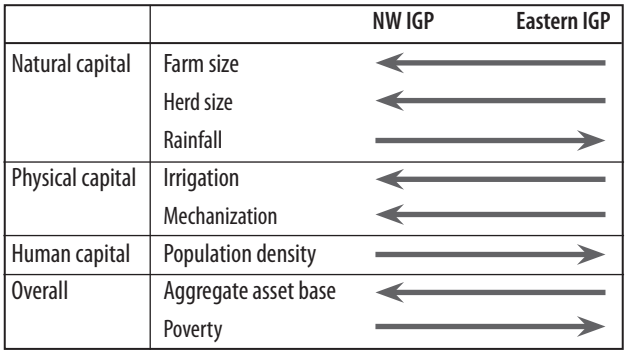

Figure 6. Stylized asset base gradients over the surveyed villages.

Social relations

The social positioning of individuals and households within society plays a major role in the communities. Social divisions clearly existed in the communities surveyed and resulted in the social exclusion of particular individuals or groups within the communities (e.g., based on caste, class/wealth, origin, gender). The West Bengal clusters had significant numbers of scheduled tribes. Gender inequity still plays a key role across subregions, reflected inter alia by gendered wage rates (Table 15), low female: male literacy ratios (Table 5) and the limited participation of women during the group meetings (Table 2). Table 13 presents some gender indicators across the IGP subregions which allow for a number of observations. First, compared to the other IGP subregions, participation of women in crop activities is significantly lower in the Trans-Gangetic Plains, which is linked to status, the more pronounced reliance on hired labor (Table 31) and mechanization (Table 20). Second, women are typically involved in livestock activities across the IGP. For the TGP this contrasts with their low involvement in field-based crop activities, and reflects that livestock activities are more homestead- and/or village-based (particularly in view of prevalent stall-feeding practices). Third, across the IGP, women's involvement in crop and livestock activities does not necessarily imply they have a say over the income derived from these activities. The reported levels of women having some say over the derived income average only two-thirds the level of their reported involvement (Table 13).

Institutions

Land and credit market. Most land is privately held and the rental and sales market of private land in the communities is largely monetized. The price of lands

Table 13. Gender issues.

	Women involved in		Women have say in	
Subregion	Crop activities (% of villages)	Livestock activities (% of villages)	Crop income (% of villages)	Livestock income (% of villages)
Trans-Gangetic Plains	50 a	100	28	50
Uttar Pradesh	78 b	89	50	78
Bihar	89 b	89	67	67
West Bengal	94 b	89	44	44
Mean	78	92	47	60
(sd, n, p)	(42,72,0.01)	(28,72,ns)	(50,72,0.14)	(49,72,0.16)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

(rental and purchase) in the TGP village clusters were markedly higher than in the other subregions (Table 14), reflecting inter alia their favorable location, productivity differentials and land (irrigation) development. The ratio of rental to purchase price averages 3%, but varies significantly between a low of 2.1% in the TGP and Bihar to a high of 3.3–4.2% in Uttar Pradesh and West Bengal (Table 14). This indicator of the average annual return to investment in land is thereby lower than the prevailing rate of interest across the IGP. This suggests that despite the high pressure on land in the IGP, financial capital remains the most limiting production factor.

One of the most striking gradients across the IGP communities surveyed is the cost of capital. Average monthly interest rates in the informal credit market vary significantly by each subregion, from a low of 1.9% in the TGP, to 3.2% in Uttar Pradesh, to 4.8% in Bihar, and 8.2% in West Bengal (Table 14). This indicator is particularly important as informal moneylenders meet the bulk of credit demand in the surveyed villages. It is only in the TGP that formal credit markets are relatively developed.

Labor market. Another particularly striking gradient across the IGP communities is the cost of labor. The average daily wage rate in the surveyed communities varies significantly by each subregion, from a high of Rs 87 in the TGP, to Rs 58 in Uttar Pradesh, to Rs 49 in Bihar, and a low of Rs 39 in West Bengal (Table 15). The average daily wage rate thereby shows an inverse relationship with the cost of capital. The wage rate broadly correlates with the surveyed villages reporting labor scarcity (Table 15). Wage rates in the TGP are more than double those reported in West Bengal. Such wage differentials are further inflated by the seasonality, with wage rates nearly doubling in the TGP, as against an increase of 20–40% in the other subregions. This indicator is particularly important as the poorest householders are typically landless agricultural laborers who primarily rely on wage labor for their income.

The relatively 'high' wage rates prevailing in the TGP and the constraints in mobilizing laborers have provided the necessary drive to the relative mechanization of agriculture in the TGP. At the same time, the wage differentials have induced significant seasonal migration across the IGP, particularly of laborers from Bihar and the Eastern Uttar Pradesh to the Trans-Gangetic Plains. Despite the low wage rates in West Bengal, seasonal mobility of Bengali laborers is typically confined to the area within the state due to language and cultural restrictions (Varma et al. 2007).

Seasonal in- and out-migrations from the surveyed villages provide a proxy indicator for their relative labor status and show some interesting variations over the IGP (Table 15). First, the TGP stands out as being the only subregion where villages reporting seasonal in-migration outnumber the corresponding out-migration. Second, Bihar stands out as the subregion where seasonal out-migration markedly outnumbers the villages with in-migration. Third, UP and West Bengal show a relative labor surplus, but less-marked than that of Bihar.

Table 14. Selected capital and land-market indicators.

Subregion	Interest rate of money lenders (%/year)	Rental price of irrigated land ('000 Rs/ha)	Purchase price of irrigated land ('000 Rs/ha)	Rental: purchase price (%)
Trans-Gangetic Plains	23 a	27 b	1300 c	2.1 a
Uttar Pradesh	38 b	15 a	470 ab	3.3 b
Bihar	58 c	11 a	590 b	2.1 a
West Bengal	98 d	14 a	320 a	4.2 b
Mean	51	17	680	3.0
(sd, n, p)	(33,46,0.00)	(10,68,0.00)	(520,68,0.00)	(1.6,44,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Table 15. Selected labor-market indicators.

Subregion	Male wage rate (Rs/day)	Female: male wage ratio	Peak: average wage ratio	Labor scarcity (% of villages)	Seasonal inmigration (% of villages)	Seasonal outmigration (% of villages)
Trans-Gangetic Plains	87 d	0.8 b	1.9 b	94 b	83 c	44 a
Uttar Pradesh	58 c	0.7 a	1.2 a	78 b	56 b	76 b
Bihar	49 b	0.7 a	1.3 a	72 b	17 a	83 b
West Bengal	39 a	0.9 b	1.4 a	33 a	44 b	78 b
Mean	57	0.8	1.5	69	50	70
(sd, n, p)	(21,70,0.00)	(0.2,68,0.03)	(0.5,53,0.00)	(46,72,0.00)	50,72,0.00)	(46,71,0.04)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Female wage rates in the surveyed communities were significantly lower than male wage rates, although this could partly reflect differences in working hours and the type of tasks performed (Table 15). The difference in gendered wage rates was largest in the UP and Bihar clusters. Amongst all the surveyed clusters across the IGP, it was only the Nadia cluster (West Bengal) that reportedly had wage rates without any gender bias.

Inputs and services. The main agricultural inputs and services are widely available across the IGP and do not seem to constrain their use (Table 16). There is a marked variation in herbicide use, with near-universal use in the TGP decreasing as one proceeds eastward to Uttar Pradesh and on to Bihar. Rates in West Bengal were again somewhat higher than those in Bihar, but similar to those in UP. However, instead of the availability of herbicides this seems associated more with the demand for herbicides and, particularly, the relative surplus of labor. There are also active markets for tractor services (all subregions), albeit less-extensive in West Bengal (Table 20).

Punjab and Haryana are the prime beneficiaries of the MSP schemes for rice and wheat (World Bank 2005:19). The FCI (Food Corporation of India) thereby procures nearly 100% of the total market arrivals of wheat in both states and approximately 90% (Punjab) and 50% (Haryana) of the total market arrivals of rice. The lower share of rice in Haryana partly reflects the greater extent of basmati cultivation, which does not fall under the scheme. The FCI procures nearly 5% of the total market arrivals of wheat and approximately 12% of the total market arrivals of rice in the UP state, whereas there is no substantial procurement in Bihar or West Bengal. The assured market and steady increases in the MSP of wheat and paddy have decreased market risk and have considerably benefited the rice-wheat producers of the NW IGP. Other crops do not benefit from similar schemes and are thereby subject to market risk. The reported prices for wheat and paddy in the surveyed villages tended to follow the MSP for 2004–05 across the IGP (for wheat Rs 6.4/kg, for paddy Rs 5.9/kg of Grade A and Rs 5.6/kg for common grades). Notwithstanding the MSP, there was still some variation (Table 17). West Bengal reported somewhat higher wheat prices, possibly associated with a wheat deficit in view of wheat being a minor crop. Rice prices were particularly low in the Bihar clusters and the Faizabad cluster of UP, likely reflecting limited marketable surplus for producers and purchasing constraints for net consumers.

For comparative purposes, selected livestock prices were compiled during the group discussions (Table 18). The reported prices of the different animal types suggest significant differences in relative livestock demands and preferences. Three broad groups appear. First, the TGP and Uttar Pradesh have markedly similar prices, where the average prices of desi cows, crossbred cows, and buffalo, approximated a ratio of 1:3:5. Second, the marked preference for buffalo over crossbred disappears in Bihar, with similar prices for both. Whereas crossbred prices in Bihar are at par with the TGP and Uttar Pradesh, buffalo prices are significantly lower. Bihar also reported the highest desi prices. Third, West Bengal also has buffalo and crossbred prices at par, albeit with the lowest level for the IGP.

Table 16. External input use (% of households reporting use).

Subregion	Purchasing improved seeds	Chemical fertilizers	Herbicides
Trans-Gangetic Plains	74	97	94 c
Uttar Pradesh	50	100	64 b
Bihar	57	100	16 a
West Bengal	59	89	47 b
Mean	60	97	58
(sd, n, p)	(35,71,0.19)	(16,72,0.13)	(46,65,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Table 17. Selected commodity prices (Rs/kg, farm gate).

Subregion	Wheat	Rice
Trans-Gangetic Plains	6.4 b	5.9 b
Uttar Pradesh	6.0 a	5.3 ab
Bihar	6.4 b	4.6 a
West Bengal	6.8 c	5.7 b
Mean	6.3	5.5
(sd, n, p)	(0.6,57,0.00)	(1.1,46,0.05)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Table 18. Selected animal and produce prices (Rs, farm gate).

Subregion	Local cow (Rs/head)	Crossbred cow (Rs/head)	Buffalo (Rs/head)	Milk (Rs/liter)
Trans-Gangetic Plains	3,800 a	10,900 b	18,200 c	10.4
Uttar Pradesh	4,000 a	11,100 b	19,000 c	10.2
Bihar	5,200 b	12,700 b	12,700 b	9.8
West Bengal	3,800 a	8,500 a	8,600 a	10.0
Mean	4,200	11,000	16,100	10.1
(sd, n, p)	(1600,58,0.03)	(3800,58,0.04)	(5300,58,0.06)	(1.4,63,ns)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Milk prices were remarkably relatively constant at Rs 10 per liter across the IGP communities surveyed (Table 18). It was only occasionally that prices specifically differentiated. Most milk was reportedly traded through local milk salesmen without industrial processing and/or consumed/sold locally within the village/household.

Organizations

In terms of organizations, the study focused the discussions on agricultural services (Table 19). The use of artificial insemination is widespread in the surveyed communities in the subtropical plains of the IGP, but has yet to make significant inroads into some of the surveyed clusters in tropical West Bengal. Artificial insemination is primarily used for crossbred (dairy) cattle and this service apparently satisfies a demand from livestock keepers—particularly in view of allowing quality-improvement of the stock and the cost of keeping male stock for breeding purposes and the correspondingly limited number of bulls in the villages. Veterinary services were nearly universally used in the TGP, but only by half the services in the Bihar clusters, suggesting problematic access and/or service delivery. Across the IGP, about half of the households reportedly used livestock and crop extension services. However, whereas there was no significant variation in livestock extension, crop extension was markedly concentrated in the TGP, reflecting the generally more favorable institutional support for agriculture. Despite the reported use of extension services, lack of access to new knowledge sources was perceived to be an issue that limited the development of the systems across the IGP communities surveyed.

Table 19. Use of selected agricultural services (% of households reporting use).

Subregion	Artificial insemination	Veterinary services	Livestock extension	Crop extension
Trans-Gangetic Plains	65 b	94 c	63	86 b
Uttar Pradesh	54 b	55 ab	40	33 a
Bihar	77 b	47 a	41	23 a
West Bengal	28 a	75 bc	53	36 a
Mean	56	69	50	48
(sd, n, p)	(44,71,0.01)	(42,60,0.01)	(43,53,ns)	(43,38,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Synthesis

The west-east asset gradient in the IGP has pronounced effects on factor prices. Compared to the eastern plains, the value of land and labor is markedly higher in the NW IGP, whereas the cost of capital is markedly lower. The institutional environment also tends to be more favorable in the NW IGP, whereas women's role in agriculture increases proceeding eastward. Figure 7 provides a stylized synthesis of some of the major observed gradients in the access modifiers over the surveyed villages. The stylized synthesis is again primarily for illustrative purposes and reiterates the most significant trends.

Trends and Shocks

The agricultural productivity of the Western IGP (Trans-Gangetic Plains, Western Uttar Pradesh) was changed dramatically by the Green Revolution. More recently, boro rice has transformed agriculture in West Bengal. Agriculture in the Eastern UP and Bihar has been much less responsive to new technologies.

Mechanization now prevails in all the surveyed clusters except in the Medinipur cluster in West Bengal (Table 20), the latter still relying primarily on animal traction (Varma et al. 2007). The widespread use of mechanization relies heavily on contracted services, as ownership of machinery is significantly less (Table 10). Tractorization (tractors replacing draft animals), which started in the northwest, and proceeded to the eastern plains, characterized the first generation of mechanization in the IGP. Combine harvesting (combine harvesters replacing

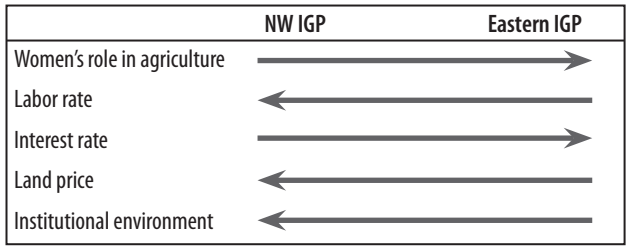

Figure 7. Stylized gradients of access modifiers over the surveyed villages.

manual labor) characterizes the second generation of mechanization. Again, the practice was picked up first in the NW IGP, driven by cost and time advantages. In the surveyed communities, combiner use was markedly concentrated and widespread in the rice-wheat systems of the TGP (Table 20). The concentration of combine harvesters in the northwest is associated with the potential cost savings (high labor cost for manual harvesting and threshing), reduced labor-management problems (seasonal labor shortages), and enhanced timeliness in this area with relatively large farm sizes and extensive rice-wheat areas (Erenstein et al. 2007c). Although not directly obvious from the surveyed clusters, combiner use is again spreading eastward despite regional labor surplus and has, for instance, been reported for UP (Beri et al. 2003:27) and observed elsewhere in the Eastern UP and West Bihar. In part, this reflects inequitable land distribution whereby larger landholdings may still opt for combiner use. The social consequences of increasing combiner use merit attention. The prevailing combiners basically harvest grain and leave the crop residue loosely and unevenly distributed in the field. More recently, the advent of the (grain) combiner has led to the increased use of a separate wheat straw combine/reaper in the TGP (particularly in the Kurukshetra cluster; Erenstein et al. 2007c), which collects and chaffs wheat straw left in the field by the combine harvester (Thakur and Papal 2005).

One of the more recent changes is the advent of zero-tillage wheat using a tractor-drawn zero-till seed drill. Laxmi et al. (2007) have already highlighted that the adoption of zero-tillage is spatially concentrated in the TGP. A recent household survey in the rice-wheat systems of Haryana has reported adoption levels of 34.5% for zero-tillage wheat (Erenstein et al. 2007a), driven by a significant 'yield effect' and a 'cost-saving effect.' Our surveyed clusters confirmed that there was widespread knowledge of zero tillage in the TGP and to a lesser extent in some of the Bihar clusters. Actual adoption in the surveyed clusters was largely limited to the Kurukshetra cluster (18% of farm households in surveyed villages) and to a lesser degree in the Patiala cluster (8%). Cost savings seemed to be the main drive behind its adoption in the surveyed communities.

The diverging agricultural history of the IGP subregions has led to significant variations in terms of poverty alleviation and agricultural productivity. Notwithstanding the ongoing adaptations in cropping and livestock practices, a striking feature of the surveyed communities across the IGP was their apparent current stagnation. Many communities thereby gave a sense that they were waiting to be helped, exhibiting a strong dependence on hoped-for government intervention and demonstrating a lack of personal initiative.

Another striking feature of the communities surveyed across the IGP was the lack of shocks having widespread impact on the rural population. Shocks seemed primarily individual and social in scope (e.g., accidents, sudden illness, loss of access rights, etc.), with immediate effects on the livelihood viability of the individuals and households concerned. The communities thereby seemed relatively stable, albeit at quite different levels of development. However, the advent of the virulent new stem rust for wheat (UG99, Mackenzie 2007; Raloff 2005; www.globalrust.org) and global warming (Ortiz et al. 2006) could have far-reaching consequences across the IGP.

Table 20. Mechanization and zero-tillage indicators.

Subregion	Use of tractor (% of farm households)	Use of combiner (% of farm households)	Knowledge of zero tillage (% of villages)	Use of zero tillage (% of households)
Trans-Gangetic Plains	89 b	57 b	78 c	8.6 b
Uttar Pradesh	90 b	5 a	11 a	0.1 a
Bihar	88 b	0 a	39 b	0.1 a
West Bengal	66 a	0 a	0 a	0.0 a
Mean	84	24	32	2.2
(sd, n, p)	(27,69,0.02)	(38,41,0.00)	(47,72,0.00)	(6.7,72,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Chapter 5 Livelihoods Strategies

The asset status of households, mediated by social factors, exogenous trends and shocks, results in the adoption and adaptation of livelihood strategies over time. Livelihood strategies are dynamic and are composed of activities that generate the means of household survival (Ellis 2000:40). The present chapter reviews the main livelihood activities in the surveyed communities: crop production, livestock, and nonfarm-based activities.

Crop Production

Crop production is the major activity for households with access to land (owned or hired, i.e., farm households). The prevalence of irrigation infrastructure typically allows for two crop seasons per year, each season with its distinct set of crops.

In the monsoonal/kharif season, rice dominates the village cropped area across the IGP clusters, but varies from nearly three-fourths in the West Bengal clusters, to half in the Trans-Gangetic Plains and about a third in Uttar Pradesh and Bihar (Table 21). The dominance of rice in West Bengal reflects the prevalence of rice as food in the tropical eastern plains. The importance of rice in the TGP reflects widespread irrigation infrastructure and the guaranteed rice market/procurement. In fact, the dominance of rice in the TGP is diluted by the Hisar cluster, where rice cultivation is limited by irrigation constraints. In the rice-wheat belt of the TGP, rice occupies three-fourths of the village area (Erenstein et al. 2007c). The lesser area under rice in the UP and Bihar clusters reflects a more varied cropping pattern. With 11% of kharif village area, horticulture is the next most prevailing crop group in terms of area in the surveyed clusters, with a nonsignificant tendency to increase from a low of 4% in the TGP subregion to a high of 19% in West Bengal. The remaining kharif village crop area is divided over a number of crops with significant variations in importance over the IGP clusters (Table 21):

- Other grain cereals (8%, primarily monsoonal maize), concentrated in the Bihar subregion and to a lesser extent in UP (the Kanpur cluster).
- Sugarcane (6%), primarily in the Meerut cluster in UP.
- Pulses/oilseeds (6%), primarily in the Hisar cluster in TGP.
- Fodder crops (5%, primarily sorghum/*jowar*), decreasing from a high of 10% in the TGP to 5–6% in Uttar Pradesh and Bihar and disappearing in West Bengal.
- Other crops (4%), primarily cotton in the Hisar cluster (TGP) and to a lesser extent tobacco in the Samastipur cluster (Bihar).

In the rabi season, wheat dominates the village cropped area in the IGP clusters, but decreases from a high of two-thirds in the Trans-Gangetic Plains to about half in Uttar Pradesh and Bihar, becoming a minor crop in the West Bengal clusters (Table 22). The dominance of wheat in the TGP subregion reflects the prevalence of wheat as food in the subtropical

Table 21. Crop share of kharif area (% of village-cultivable area).

Subregion	Rice	Other cereals	Sugarcane	Horticulture	Pulses/oilseeds	Other crops	Fodder crops
Trans-Gangetic Plains	50 b	5 a	3 a	4	13 b	10 b	10 c
Uttar Pradesh	30 a	9 ab	22 b	10	3 a	0 a	5 b
Bihar	37 ab	15 b	1 a	12	5 a	6 ab	6 bc
West Bengal	71 c	1 a	0 a	19	1 a	0 a	0 a
Mean [n=72]	47	8	6	11	6	4	5
(sd, p)	(36,.00)	(15,.03)	(20,.00)	(20,ns)	(12,.01)	(14,.06)	(7,.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

northwest plains, the traditional wheat heartland and India's breadbasket, aided by widespread irrigation infrastructure and a guaranteed wheat market per procurement. The remaining village crop area (rabi) is divided over a number of crops with generally (except for pulses/oilseeds) significant variations in importance over the IGP clusters (Table 22):

- Horticulture (12%), primarily in the downstream plains of the Bihar and West Bengal subregions.
- Pulses/oilseeds (10%).
- Other grain cereals (8%), primarily in the downstream subregions of Bihar (primarily winter maize) and West Bengal (primarily boro rice).
- Fodder crops (4%), decreasing from a high of 9% in the TGP subregion to 3–5% in Uttar Pradesh and Bihar and disappearing in West Bengal.
- Sugarcane (3%), primarily in the Meerut cluster in Uttar Pradesh.
- Other crops (1%), primarily jute in the West Bengal clusters.

Overall, rice-wheat was the main cropping systems in the surveyed communities (38%; Table 23), though decreasing from 61% of villages in the TGP subregion to 39% in Bihar and subsequently disappearing in the West Bengal clusters. Rice-based and wheat-based systems prevailed in 22% and 18% of the communities, respectively. However, whereas rice-based systems were markedly concentrated in the West Bengal subregion, wheat-based systems were spread over the surveyed clusters in the three upstream subregions. Maize-wheat systems and maize-based systems were reported in 8% and 3% of the communities, respectively, primarily in the Bihar and Uttar Pradesh subregions. Other cropping systems were reported in 11% of the communities.

The seasonal cropping intensity in the surveyed villages averages 88% in kharif and 81% in rabi, resulting in an annual cropping index of 169% (Table 24). There is a (nonsignificant) tendency for cropping intensity to decrease from a high of 182% in the TGP subregion to a low of 155% in the West Bengal subregion, where irrigation constraints limit the rabi area.

Table 22. Crop share of the rabi area (% of village-cultivable area).

Subregion	Wheat	Other cereals	Sugarcane	Horticulture	Pulses/- oilseeds	Other crops	Fodder crops
Trans-Gangetic Plains	66 c	0 a	1 a	2 a	8	0 a	9 c
Uttar Pradesh	53 b	0 a	11 b	7 a	11	0 a	5 b
Bihar	48 b	15 b	1 a	17 b	6	0 a	3 b
West Bengal	5 a	16 b	0 a	23 b	14	4 b	0 a
Mean [n=72]	43	8	3	12	10	1	4
(sd, p)	(29,.00)	(18,.00)	(10,.00)	(19,.00)	(13,ns)	(4,.02)	(6,.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

Table 23. Main cropping system (% of villages)

Subregion	Rice-based	Rice-wheat-based	Wheat- based	Wheat-maize-based	Maize- based	Based on others
Trans-Gangetic Plains	6	61	22	0	0	11
Uttar Pradesh	0	50	22	17	0	11
Bihar	6	39	22	17	11	6
West Bengal	78	0	6	0	0	17
Indo-Gangetic Plains [n=72]	22	38	18	8	3	11

Table 24. Cropping intensity indicators (% of cultivable land).

Subregion	Kharif	Rabi	Annual
Trans-Gangetic Plains	96	86 b	182
Uttar Pradesh	80	87 b	166
Bihar	83	89 b	172
West Bengal	93	62 a	155
Mean	88	81	169
(sd, n, p)	(25,72,0.16)	(29,72,0.03)	(37,72,0.17)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

The reported wheat and paddy yields average 3.1 and 4.1 metric tons per hectare (mt/ha), respectively, but with significant variation between subregions (Table 25). Wheat yields were significantly higher in the TGP and Uttar Pradesh subregions (3.3–3.8 mt/ha) compared to Bihar and West Bengal subregions (2.5–2.6 mt/ha). This reflects the more favorable wheat-growing conditions in the northwest in terms of a cooler climate, more timely planting, and more developed irrigation infrastructure. Moving downstream, the wheat-growing season tends to become shorter due to the onset of terminal heat. The reported paddy yields are highest in the TGP subregion (6.3 mt/ha), intermediate in West Bengal (4.4 mt/ha), and lowest in the Uttar Pradesh and Bihar subregions. The high yields in the TGP reflect irrigation facilities and widespread input use.

The share of wheat and paddy produce marketed averages 36% and 56%, respectively, but with significant variation between subregions (Table 25). The TGP stands out with high marketing shares for both crops emphasizing the pronounced market orientation, particularly for rice. Only about one-fifth of the wheat produce in the other subregions was reportedly marketed, highlighting that the remainder was used primarily for domestic consumption and reiterating constraints in productivity and farm size. A striking feature of these eastern plains is that most farm households are, by compulsion, primarily home-consumption-oriented, having limited marketable surplus for wheat and rice. Instead, many of these smallholders relied on other activities (including cultivation of crops other than rice and wheat) to generate cash income.

Livestock Production and Marketing

The village surveys confirmed widespread ownership of livestock to complement the rice- and wheat-based cropping systems as the basis of rural livelihoods. The role and contribution of livestock differ between the northwest and the eastern plains of the IGP.

Table 25. Rice and wheat: Yields and marketed surplus.

Subregion	Wheat (mt/ha)	Paddy (mt/ha)	Marketed share of wheat (%)	Marketed share of paddy (%)
Trans-Gangetic Plains	3.8 b	6.3 c	68 b	95 c
Uttar Pradesh	3.3 b	3.4 a	23 a	41 ab
Bihar	2.6 a	2.9 a	19 a	29 a
West Bengal	2.5 a	4.4 b	21 a	50 b
Mean	3.1	4.1	36	56
(sd, n, p)	(0.8,56,0.00)	(1.7,56,0.00)	(30,54,0.00)	(36,50,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Buffalo are the prevailing livestock type in the northwest and show a marked decline proceeding downstream: from nearly all households owning buffalo in the TGP clusters to only a minority of households in the West Bengal clusters (Table 26). Similarly, there is an average of 2.5 buffalo heads per village household in the TGP, which decreases to insignificant levels in West Bengal (Table 27). Ownership of desi cows is not widespread, but does show a significant opposite trend, being relatively common in the West Bengal clusters (59% of households owning, with an average of 1.4 heads per village household) and relatively limited in the other clusters (8–15% households owning with an average of 0.1–0.3 head per village household). In contrast, there was no significant variation in terms of dairy crossbreds (24% of households owning, with an average of 0.3 head per village household). Dairy animals are held by both smallholders and larger farmers.

The reported dairy herds reflect the underlying investment trends in livestock. In each location, the number of desi cows was declining, being replaced by buffalo and crossbred cows. The choice of households between crossbred and buffalo varied reflecting production trade-offs in terms of quality and quantity of milk, sturdiness of animals, and availability of artificial-insemination facilities. The general preference for buffalo in the upstream clusters reflects the perceived lower production risks due to its resistance to adverse weather; preference for high-fat milk with a generally higher milk price and good market opportunities; and a better market for unproductive animals.

A quarter of the households kept draft cattle, primarily male buffalo and bullocks. Draft cattle were particularly common in the NW IGP and downstream West Bengal (Table 26). The important role in the northwest shows that, despite widespread tractorization of tillage operations, draft cattle still fulfill important transport functions. The important role in West Bengal relates to their still important tillage function, particularly in the West Medinipur cluster.

Small ruminants were relatively absent in the northwest but became more prominent moving eastward (caprine and ovine in Tables 26 and 27): over half of the households reportedly owned small ruminants, with an average of 2.4 heads

per village household in West Bengal. Small ruminants are particularly common among the smallholders and landless. The preference for small ruminants over large ruminants in the eastern plains seems associated with capital constraints, easier monetization (i.e., more liquid assets), and more grazing possibilities.

Backyard poultry is relatively absent in the upstream IGP subregions, but becomes strikingly common in West Bengal (57% of households, including ducks). Pigs and equines were relatively uncommon (Tables 26 and 27).

The types and number of livestock sum up to an average herd size of 3.0 cow equivalents per household. However, the herd size is 50% above average in the TGP clusters, and 50% below average in the Bihar clusters (Table 28). The important role of livestock extends to the landless, with landless households typically also keeping various types of livestock. Nonetheless, the average aggregate herd size shows a strikingly inverse relationship with the prevailing poverty levels reported in the secondary data (Table 4).

Dairy productivity was relatively low across the IGP. Still, on average across all sites, 62% of milk output was reportedly sold and 38% kept for domestic consumption (Table 28). The dairy enterprise thereby provides an important and regular source of cash income to the farm household. Sales and purchases of livestock were not regular occurrences (Table 28). Livestock transactions tended to be local, except for some UP clusters where half the villages reported sales outside the locality (Table 28).

Table 26. Livestock ownership (% of households).

Subregion	Buffalo	Local cows	Crossbred cows	Draft animals	Caprine and ovine	Pigs	Poultry	Equine and camel
Trans-Gangetic Plains	97 d	10 a	18	40 b	1 a	0	1 a	4
Uttar Pradesh	74 c	15 a	18	21 ab	22 b	3	0 a	0
Bihar	35 b	8 a	37	11 a	42 c	2	4 a	1
West Bengal	3 a	59 b	23	33 b	53 c	2	57 b	1
Mean [n=72]	52	23	24	26	29	2	15	1
(sd, p)	(42,.00)	(32,.00)	(32,ns)	(33,.04)	(33,.00)	(4,ns)	(33,.00)	(6,.16)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

Table 27. Livestock numbers (heads per household).

Subregion	Buffalo	Local cows	Crossbred cows	Draft animals	Caprine and ovine	Pigs	Poultry	Equine and camel
Trans-Gangetic Plains	2.5 c	0.2 a	0.2	0.4 ab	0.4 a	0.0	0.1 a	0.0
Uttar Pradesh	1.6 b	0.3 a	0.2	0.2 ab	1.2 ab	0.2	0.6 a	0.0
Bihar	0.5 a	0.1 a	0.4	0.1 a	1.6 bc	0.1	1.0 a	0.0
West Bengal	0.1 a	1.4 b	0.4	0.4 b	2.4 c	0.0	3.4 b	0.0
Mean	1.2	0.5	0.3	0.3	1.4	0.1	1.3	0.0
(sd, n, p)	(1.4,.00)	(.8,.00)	(.5,ns)	(.5,.10)	(1.8,.01)	(.2,.17)	(3.0,.03)	(.1,0.17)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

Table 28. Livestock and milk sales.

Subregion	Herd size (no. of cow equivalents/ household)	Regular livestock sales (% of villages)	Nonlocal livestock sales (% of villages)	Marketed share of milk (% of output)
Trans-Gangetic Plains	4.6 c	28	28 a	59
Uttar Pradesh	3.2 b	18	53 b	70
Bihar	1.5 a	11	17 a	65
West Bengal	2.8 b	6	13 a	52
Mean	3.0	16	28	62
(sd, n, p)	(2.2,72,0.00)	(37,69,ns)	(45,69,0.04)	(29,64,ns)

Notes: Data preceding different letters differ significantly – Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

Nonfarm-Based Activities

In addition to crop and livestock production, rural households in the surveyed villages are variously engaged in different types of off-farm activities. Such activities typically include farm labor on other farms, self-employment and employment/service elsewhere. Except for the TGP subregion, at least three-fourths of the surveyed villages in the other clusters mentioned members of some households seasonally migrating out of the village (Table 15), mainly to work as farm laborers in other villages and to a lesser extent as nonfarm laborers (e.g., masonry, industry, trading). Working as a farm laborer was the main employment for the resident landless. The engagement in farm labor can be seen, particularly, as an indicator of relative poverty due to its low wages, low status and seasonality, and is often associated with landlessness or a very smallholding.

Relative Importance of Livelihood Strategies

Across all the surveyed villages in the IGP, the main livelihood activities were crop farming (58%), farm labor (19%), livestock rearing (10%), employment outside the district (10%), and self-employment (3%) (Table 29). It was only those employed outside the district who showed significant variation over the clusters, being most common in the Bihar subregion and to a lesser extent in West Bengal. Although not significant, there is also a tendency for the relative importance of cropping as the main livelihood activity to decrease as one proceeds from the TGP clusters to the Bihar clusters, and again increasing somewhat in the West Bengal clusters. Overall though, there was relatively limited variation over the clusters, despite the differential asset base available to the households, as reviewed in the previous chapter.

Across surveyed villages, smallholders predominated (64%), followed by landless poor (29%), and large farmers (5%) (Table 30). Wealth is closely associated with access to land in these rural communities, and consequently landless rich households are uncommon (2%), and often associated with nonagricultural opportunities. Consistent with secondary data (**Annex** 1), the TGP subregion reported the highest share of large farmers. The share of landless poor was relatively low in the communities surveyed in the Uttar Pradesh subregion. Despite the reportedly widespread land reforms in West Bengal (Varma et al. 2007), the share of landless poor in the surveyed communities is still relatively high and is comparable to that reported for the neighboring Bihar subregion.

Access to land thus provides a key indicator for differentiating amongst household livelihood strategies. For the larger-landed households crop production appeared as the main livelihood source. For smallholders, crop and livestock are typically

Table 29. Main livelihood activity (% of households).

Subregion	Crop farming	Livestock rearing	Employed on other farms	Self-employed	Employed outside district
Trans-Gangetic Plains	65	13	14	3	5 a
Uttar Pradesh	57	12	18	6	7 ab
Bihar	47	11	21	2	18 c
West Bengal	60	4	23	2	11 b
Mean [n=72]	58	10	19	3	10
(sd, p)	(23,0.11)	(13,0.12)	(16,ns)	(6,ns)	(11,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

Table 30. Categorization of village households (% of households).

Subregion	Landless rich	Landless poor	Small farmers (<4 ha)	Large farmers (>4ha)
Trans-Gangetic Plains	2	29 ab	57	12 b
Uttar Pradesh	0	16 a	76	7 ab
Bihar	3	35 b	61	1 a
West Bengal	2	35 b	61	2 a
Mean [n=72]	2	29	64	5
(sd, p)	(5,ns)	(24,0.06)	(26,0.13)	(14,0.06)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

complementary although, to a large extent, livestock depend on the crop enterprise. Landless households depend primarily on their labor asset, with livestock providing an important contribution.

Labor plays another key role in shaping the household livelihood strategies, being a major cost of production for the landed and a major income source for the landless. Clearly, the continuing spread of agricultural mechanization has, thereby, different implications. Family labor provides the lion's share of the labor needs for crop and livestock production. Half the farm households use casual labor to supplement family labor in crop production (Table 31). However, there is a marked gradient in the reliance on casual labor: contracting casual labor for crop operations is the rule in the northwest but decreases as one proceeds eastward to the Bihar subregion, and again increasing somewhat in West Bengal. A quarter of the TGP farm households reported using permanent labor for crops and livestock and 9% of the households contracted casual labor for livestock activities. In the other clusters, these other uses of nonfamily labor are largely sporadic (Table 31), reiterating their smaller scale, less-commercial orientation and greater reliance on family labor.

Synthesis

The west-east asset gradient in the IGP has pronounced effects on livelihood strategies. Compared to the eastern plains, the NW IGP has a pronounced emphasis on the wheat and buffalo production, the rice-wheat cropping system, cereal market orientation, and fodder crop cultivation. The eastern plains have a marked emphasis on rice, tend to have more diverse cropping patterns, have more prominence on desi/local cattle and small ruminants, with agricultural labor as a prominent livelihood. Figure 7 provides a stylized synthesis of some of the major observed gradients in livelihood strategies over the surveyed villages. The stylized synthesis is again primarily for illustrative purposes and reiterates the most significant trends.

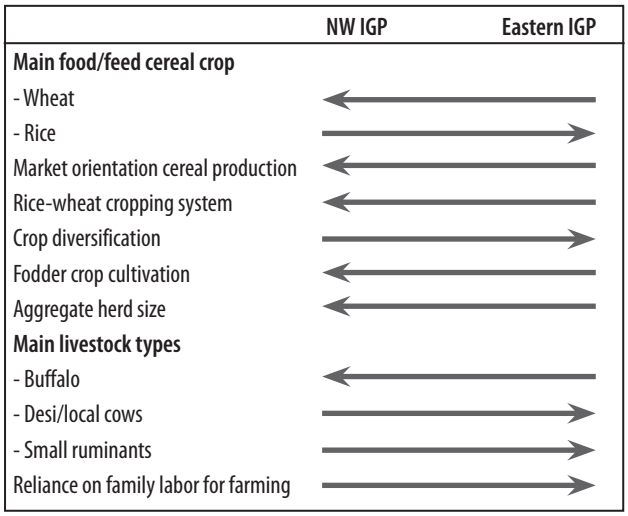

Figure 8. Stylized gradients of livelihood strategies over the surveyed villages.

Table 31. Labor use by enterprise.

	Crop		Livestock	
Subregion	Use of casual labor (% of farm households)	Use of permanent labor (% of farm households)	Use of casual labor (% of households)	Use of permanent labor (% of households)
Trans-Gangetic Plains	81 c	25 b	9 b	24 b
Uttar Pradesh	51 b	6 a	4 ab	0 a
Bihar	31 a	0 a	0 a	0 a
West Bengal	52 b	0 a	1 a	0 a
Mean [n=72]	54	8	4	6
(sd, p)	(39, 0.00)	(21, 0.00)	(12,0.09)	(19, 0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Chapter 6 Crop-Livestock Interactions

The two previous chapters presented the platforms and strategies of livelihoods pursued by the surveyed communities across the IGP. Within this context, the present chapter specifically looks into the crop-livestock interactions. We start by reviewing the flows of the crop activities into the livestock activities. Particular emphasis is placed on understanding crop-residue management and livestock-feeding practices. We subsequently address the reverse flows from livestock into crop activities, particularly in terms of manure and traction services. The chapter ends with an assessment of crop-livestock interactions.

Crop-Residue Management

Crop residues (straw) constitute an important byproduct of crop production and all the 72 surveyed communities reported the use of these residues as animal feed. The prevalence of the use of crop residues as animal feed amongst the rural households is particularly widespread for wheat and rice (Table 32). However, the overall preference for wheat and rice straw in the IGP as a whole masks a significant variation over the subregions. Wheat straw prevails as the preferred feed with near-universal use in the northern plains, from the TGP to the Bihar subregions. In West Bengal, though, wheat straw is not preferred as feed and its use as feed is marginal. The use of rice straw shows a marked opposite gradient. The use of rice straw as animal feed amongst the rural households is near-universal in the West Bengal subregion, and decreases proceeding upstream to only 28% of households in the TGP. For rice straw within the TGP, only crop residues from fine-grain rice varieties (particularly basmati) are more widely appreciated and used as animal feed (Erenstein et al. 2007c). The preference for rice straw observed in West Bengal extends to Bangladesh (Varma et al. 2007). Two factors largely explain this differential use of wheat and rice straw in the IGP. The first factor is tradition. Wheat is the traditional cereal crop in NW IGP but it is a relatively recent arrival in the Eastern IGP. Conversely, rice is the traditional cereal crop in Eastern IGP, but it is a relatively recent arrival in NW IGP. These changes in the cropping pattern are associated with the Green Revolution. The prevalence of wheat or rice as the traditional and prevailing food crop in the subregions of the IGP has resulted in a tradition of the corresponding use of cereal straw as livestock feed. A second factor is that wheat straw is relatively sturdy and its use as animal feed has benefited from the mechanical threshing that now prevails in the traditional wheat-growing areas. This mechanical threshing chops the wheat straw into *bhusa* (small pieces which are more palatable). However, mechanized threshing has yet to make significant inroads into West Bengal.

There is also some feed use of maize residues and other crops (38% and 19%, respectively, only for those villages cultivating the respective crops; Table 32). Their relative use varies over sites but can provide important feed sources. For instance, maize residues were a seasonally important feed source in some of the Bihar clusters (Thorpe et al. 2007). Green sugarcane tops were widely used as forage in the sugarcane belt of UP (Singh et al. 2007). Other crop residues include those of millet and sorghum (particularly in the semiarid Hisar cluster of the TGP) and pulses (e.g., Bihar subregion).

The pressure on crop and cereal residues in West Bengal is markedly higher than in the other IGP subregions (Table 33). This is a reflection of West Bengal having the lowest farm sizes with

Table 32. Crop-residue collection for ex-situ livestock feed (% of households).

Subregion	Wheat	Rice	Maize	Other crops
Trans-Gangetic Plains	95 b	28 a	0	30 b
Uttar Pradesh	100 b	69 b	31	29 b
Bihar	100 b	76 b	46	19 ab
West Bengal	4 a	99 c	25	0 a
Mean	78	70	38	19
(sd, n, p)	(40,68,0.00)	(42,66,0.00)	(47,26,ns)	(39,71,0.08)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

intermediate herd sizes (in cow equivalents) and a relatively low cropping intensity (particularly due to limited irrigation). Because of the limited wheat area in West Bengal the nominal pressure on wheat residues is inflated (Table 33), although this is of limited practical interest in view of the limited feed use of wheat residues in this subregion. There is no significant variation in the pressure on rice residues though (Table 33). It is worth flagging that these aggregate indicators are in area terms and thereby fail to capture variations in productivity and use intensity, particularly in view of the significant variation in (cereal) grain and corresponding biomass yields (Table 25) and the west-east gradient for planted fodder crops (Figure 8).

Except for the universal practice of using crop residues for ex-situ livestock feed, there is a significant variation in terms of crop-residue management practices (Table 34).

Except for the NW IGP, the cereal crops are primarily harvested manually, whereby the wheat and rice plants are cut at some level above the soil surface. The crop bundles are subsequently brought to a central place in the field or elsewhere for threshing, which facilitates the collection and use of crop residues. Threshing of manually harvested wheat in the IGP is typically done with a mechanical thresher that chaffs the straw into bhusa (small pieces) ready to be used as livestock feed. It is only in West Bengal that wheat is typically threshed manually. Bhusa is primarily stored in the open in bhusa stacks or inside the farm houses. In the TGP and Uttar Pradesh subregions, storage and use of wheat straw are year-round, whereas duration of storage and use decline proceeding downstream (Table 35). The manually harvested paddy in the IGP is threshed in various ways (e.g., manually, trampling by oxen or tractor, mechanic thresher), but the threshing generally keeps the rice residue relatively intact. The remaining rice-residue bundles when stored are kept in the open in heaps or stacks. The use of rice residue as livestock feed is typically seasonal and storage is therefore typically limited to 4–5 months. It was only in the West Bengal subregion that storage and use of rice straw were year-round (Table 35). Prior to feeding, rice residues are chaffed, typically with a mechanical chaff-cutter except in West Bengal where manual chaffing prevails. The practices of labor-intensive residue management and use are a particularly striking feature of West Bengal (Varma et al. 2007).

In the surveyed communities, the use of a combine harvester for rice and wheat was largely limited to the rice-wheat belt of the TGP (Table 20). The recovery of byproducts by combine harvesting is more problematic as the crop is cut well above ground level and the cut residues are spread unevenly over the harvested fields. To address the potential loss of wheat residues when combining, a bhusa/chaff combine was developed by local manufacturers in Punjab in the mid-1980s and has become increasingly popular in the rice-wheat belt of the TGP subregion. The tractor-pulled machine collects the straw, cuts the stubbles, processes the straw into bhusa and collects it in an attached enclosed trailer (Erenstein et al. 2007c).

The use of crop residue as livestock feed primarily relies on harvesting and storing the residues for ex-situ use (stall feeding). In-situ stubble-grazing complements the collection of crop residues for ex-situ use from the same cereal field. Stubble-grazing shows a marked west-east gradient in the IGP, from low levels in the TGP to high levels in the eastern plains (Table 34). In the Bihar subregion, stubble-grazing was about equally common in wheat and rice fields. But in the West Bengal subregion, rice-stubble-grazing was markedly commoner, whereas in the UP subregion wheat-stubble-grazing was relatively commoner (Table 36). This mirrors the respective preference for wheat or rice straw, but this is also associated with irrigation constraints and the associated cropping patterns. The limited stubble-grazing reported in the TGP was confined to the irrigation-limited wheat-cotton belt (the Hisar cluster; Erenstein et al. 2007c).

Table 33. Indicators of livestock pressure on crop residues (cow equivalents per ha at the village level).

Subregion	On crop residue (cow equivalents/ha)	On cereal residue (cow equivalents/ha)	On wheat residue (cow equivalents/ha)	On rice residue (cow equivalents/ha)
Trans-Gangetic Plains	1.1 a	2.0 a	3.9 a	7.2
Uttar Pradesh	2.2 a	6.1 a	9.9 a	26.8
Bihar	1.9 a	2.8 a	7.3 a	24.4
West Bengal	7.2 b	11.3 b	252.6 b	15.4
Mean	3.1	5.5	55	18.9
(sd, n, p)	(5.6,72,0.00)	(9.2,72,0.01)	(209,67,0.00)	(31.5,66,ns)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

About two-thirds of the surveyed villages reported the use of crop residues for non-feed uses, primarily the use of straw as construction material (e.g., thatching and ropes) and fuel. The non-feed uses increase along a west-east gradient in the IGP, from low levels in the Uttar Pradesh subregion to high levels in the eastern plains (Table 34). This reflects a generally increasing pressure on crop residues either for feed or other uses along the west-east gradient in the IGP. The relatively high incidence of reported non-feed uses in the TGP subregion needs to be qualified as, generally, the quantities involved in non-feed uses were relatively small except for those instances where rice residues were used for industrial processing (cardboard factories, paper mills; Erenstein et al. 2007c).

The practice of in-situ burning of crop residues is markedly concentrated in the NW IGP (Table 34). This particularly applies to rice straw, which not only has limited value as livestock feed or for non-feed uses there but is also generally left in the field after the harvest and subsequently burnt as a land-preparation measure. In-situ burning is also associated with the prevalence of combine harvesting in the northwest and the more problematic recovery of byproducts. In view of the intensive residue utilization in the downstream IGP, generally, limited (rice or wheat) residues remain in the field at the time of land preparation, explaining why the in-situ burning of crop residues is uncommon there.

Several types of crop-residue transactions exist between households in the surveyed clusters (Table 37). Nearly all the surveyed villages reported sales of crop residues by farmers. In about a third of the villages, crop residues were also used as in-kind payment, often interlinked with the labor market. In-kind payment shows a marked decline along a west-east gradient in the IGP, from being relatively common (three-fifth of the villages) in the TGP subregion to its absence in West Bengal. In about one-fifth of the villages, crop residues were sometimes given away. Crop-residue gifts were reportedly confined to the TGP and Uttar Pradesh subregions and often restricted to rice there. The nonmonetized residue transactions and residue gifts are associated with the larger farm sizes in the NW IGP and the corresponding relative resource and straw scarcity in the eastern plains.

Nearly one-third of the households in the surveyed communities are engaged in the wheat-residue market, with 8% being net sellers and 22% net buyers (Table 38). However, wheat-residue transactions were confined to the subtropical IGP, not being reported for West Bengal. In terms of wheat-straw sales, there was a marked decline along the west-east gradient, net sellers being most common (one-sixth of the households) in the TGP subregion and absent in West Bengal (Table 38). In terms of wheat-straw purchases, there was an opposite tendency (not significant) of net buyers to increase along the west-east gradient in

Table 34. Crop-residue management practices (% of villages).

Subregion	Ex-situ feed use	In-situ grazing	Non-feed uses	In-situ burning
Trans-Gangetic Plains	100	11 a	72 bc	87 b
Uttar Pradesh	100	39 b	44 a	33 a
Bihar	100	44 bc	67 ab	11 a
West Bengal	100	67 c	94 c	11 a
Mean	100	40	69	33
(sd, n, p)	(0,72,ns)	(49,72,0.01)	(46,72,0.01)	(48,72,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

Table 35. Duration of crop-residue storage (months).

Subregion	Wheat	Rice
Trans-Gangetic Plains	12 c	5 a
Uttar Pradesh	12 c	4 a
Bihar	9 b	5 a
West Bengal	4 a	12 b
Mean	10	7
(sd, n, p)	(3,57,0.00)	(4,54,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Table 36. Crop residue grazed in-situ (% of households).

Subregion	Wheat	Rice
Trans-Gangetic Plains	0 a	0 a
Uttar Pradesh	34 b	11 ab
Bihar	38 b	31 b
West Bengal	23 ab	67 c
Mean	25	29
(sd, n, p)	(42,66,0.04)	(45,66,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Table 37. Crop-residue transaction practices (% of villages).

Subregion	Sales	In-kind payment	Given away
Trans-Gangetic Plains	94	61 c	50 b
Uttar Pradesh	89	29 b	39 b
Bihar	100	33 b	0 a
West Bengal	100	0 a	0 a
Mean	96	31	22
(sd, n, p)	(20,72,ns)	(47,71,0.00)	(42,72,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

the subtropical plains, from a low of one-fourth in the TGP subregion to a high of one-third in Bihar (Table 38). This illustrates that net sellers are increasingly outnumbered by net buyers, reiterating the relative scarcity of wheat residue in the eastern subtropical IGP and the associated limited farm/wheat area per household. Residue transactions tend to be local and are mainly directly between buyer and seller, with only some reported traders.

The average price of wheat residue varied significantly across subregions and seasons. The price of wheat straw was higher in the Bihar subregion (Rs 1.7/kg) than in the TGP and Uttar Pradesh subregions (Rs 1.2–1.4/kg; Table 39). Each site also showed seasonal variation, whereby the overall average Rs 1.4/kg across sites varied from a seasonal low of Rs 1.2/kg after the wheat harvest to a seasonal high of Rs 1.9/kg during the winter months. Wheat residues thereby provide a significant contribution to the income derived from wheat production, although their value seems relatively low compared to their importance for livestock production.

The market for rice residue shows some interesting contrasts with that for wheat residue. Transactions in rice residue are markedly concentrated in the downstream Bihar and West Bengal subregions, with one out of four to five households being net buyers and up to one out of five being net sellers. In contrast, the market for rice residue is relatively thin in the TGP and Uttar Pradesh subregions, with the engagement of only one out of ten households in the surveyed communities (Table 37). There are also three marked variations in straw prices. First, the price of rice straw is markedly higher in the downstream Bihar and West Bengal subregions (Rs 0.8/kg) than in the upstream subregions (Rs 0.1–0.2/kg; Table 39). This is clearly associated with the difference in intensity of transactions in straw in the two areas. It also explains why rice residues were sometimes simply given to the landless and smallholders in the upstream plains. Second, wheat straw typically has a markedly higher value than rice straw (Table 39). Third, the prices of rice straw were more distinctly affected by varieties (e.g., preference for basmati straw over non-basmati straw; Erenstein et al. 2007c) and cropping seasons (e.g., preference for *aman* rice over boro rice; Varma et al. 2007). Similar to wheat though, rice straw also showed seasonal variation (Table 39). Straw-quality factors did not play a major role in determining prices of either wheat straw or rice straw. Varietal choice for wheat and rice mainly reflected considerations of grain yields.

Table 38. Categorization of households as deficit or surplus in crop residue (% of households).

Subregion	Surplus (net seller)		Deficit (net buyer)	
	Wheat	Rice	Wheat	Rice
Trans-Gangetic Plains	16 b	9	24 b	0 a
Uttar Pradesh	8 ab	7	29 b	2 a
Bihar	7 a	4	34 b	21 b
West Bengal	0 a	21	0 a	25 b
Mean	8	10	22	12
(sd, n, p)	(14,67,0.02)	(24,66,0.15)	(29,72,0.00)	(24,72,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Livestock Feed Inputs and Availability

Crop residues provide the predominant feed for the households in the surveyed communities in the IGP. In all surveyed communities, ruminant livestock are fed a basal diet based largely on cereal straw throughout the year. The type of straw used varies over the IGP, with wheat bhusa prevailing in the NW IGP and being increasingly complemented with rice straw proceeding eastward, and being replaced completely by rice straw in the downstream West Bengal subregion. Where available, use is also made of other crop residues, including maize, sugarcane (green tops; Singh et al. 2007), pulses and oilseeds and vegetables. The basal diet of crop residues is supplemented with green fodder, grazing,

Table 39. Crop-residue prices (Rs/kg).

Subregion	Wheat			Rice		
	Average	Peak	Trough	Average	Peak	Trough
TGP	1.4 a	1.9 a	1.2 a	0.2 a	0.3	0.2
UP	1.2 a	1.5 a	1.0 a	0.1 a	-	-
Bihar	1.7 b	2.4 b	1.4 b	0.8 b	1.4	0.6
W Bengal	-	-	-	0.8 b	1.2	0.6
Mean	1.4	1.9	1.2	0.7	1.2	0.6
(sd, n, p)	(0.5,54,0.00)	(0.7,51,0.00)	(0.4,51,0.01)	(0.6,35,0.03)	(1.1,24,ns)	(0.3,24,ns)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

collected grasses/forage, other crop byproducts, and compound feed (Table 40).

The use of green fodder shows a marked decline along a west-east gradient in the IGP, from being widespread (three-fourth of households) in the TGP subregion to its virtual absence in West Bengal (Table 40). This marked gradient mirrors the decline in cultivated fodder area (Tables 21 and 22). Except for the West Bengal subregion, most households in the IGP had a chaff-cutter, which was used for chopping the green fodder and the crop residues not chopped during harvesting/threshing.

The diet is generally complemented with a range of nutrient-dense types of crop byproducts (Table 40). These byproducts are fed as straights or as homemade mixes and include a range of products like oilseed-cakes, wheat and rice bran, pulses/oilseed residues and grounded grains of gram, wheat, maize, and broken rice. These byproducts are both bought and come from own-farms, with reportedly variable qualities. Only one out of four households reportedly uses compound feed, a practice relatively common in Bihar and the TGP subregions (Table 40). The byproducts and compound feeds are primarily used to increase the milk yield of lactating milch animals. Their use is reported as either stable or increasing in the surveyed communities, although current feed rates appear to be low. The reported prices varied by locality but were generally lower than the prevailing milk price. This suggests that their increased use would show a good profit. In the same way, there were limited reports of purchasing mineral mixtures, despite known links between poor reproductive performance and mineral deficiencies.

Bovines dominate the NW IGP (Table 27) and with practically no grazing land, the animals are generally stall-fed in or near the household compound throughout the year. Proceeding towards the Eastern IGP, bovines remain primarily stall-fed on crop residues, but this is increasingly supplemented with:

- grazing, particularly where fallow or barren lands are available and
- collected grasses/forage, e.g., from barren land, field boundaries and roadsides.

These fodder sources are also important for small ruminants. In the eastern plains, the prospects of grazing animals and collection of forage were aided by the relatively low opportunity cost of labor. As a result, there is a marked increase in both grazing and collected forage along a west-east gradient in the IGP, from low levels in the TGP subregion to high levels in West Bengal (Table 40).

Overall availability of fodder in the surveyed communities seemed more problematic in the eastern plains, hampered by the limited irrigation infrastructure and population pressure. This was compounded by the seasonality of fodder. For landed households forage is mainly home-produced and availability more manageable, particularly in the NW IGP. Purchases are important sources of feed to alleviate shortfalls in home-produced forage for a number of households (Tables 37 and 38). Marginalized and landless households face a more dire scarcity of forage as they often lack the resources for feed purchase and thereby often primarily depend on a combination of grazing and collection of grasses, tree leaves and crop residues from the farming community.

Current practices in feed management reflect farmers' response to the prevailing opportunities and constraints. Bovines are an integral part of the livelihood strategies of most landed households throughout the IGP, but they were not perceived as primary income earners for their owners. Instead, bovines are converters of readily available crop residues into milk both for household consumption and as a means of regular cash and accumulating the herd growth. The landless households concentrated mainly on small ruminants and pigs in the eastern plains with fast herd growth as an important means of accumulation and source of cash.

Table 40. Use of feed sources (% of households).

Subregion	Other crop by product*	Compound feed	Grazing	Collected grasses/forage	Green fodder
Trans-Gangetic Plains	94	31 ab	9 a	27 a	75 c
Uttar Pradesh	78	16 a	31 b	50 b	62 bc
Bihar	79	39 b	44 b	48 ab	44 b
West Bengal	74	13 a	84 c	84 c	1 a
Mean	81	25	42	53	45
(sd, n, p)	(35,72,ns)	(35,72,0.08)	(46,69,0.00)	(41,67,0.00)	(46,70,0.00)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison. ns: nonsignificant.

* Other than crop residues.

Livestock Input to Crop Production

Traditionally, male bovines were the main traction source in agriculture and rural transport. But with increased tractorization, the relative importance of livestock for traction has declined. Although 84% of farm households use tractors for crop production in the IGP surveyed communities, more than one-third (also) use draft animals (Table 41). There is significant variation over the IGP though. The use of draft animals is particularly widespread in West Bengal with 60% of farm households reportedly using them. West Bengal also stood out for having markedly lower tractor use (66%), reiterating its relatively limited mechanization. Tractor use was markedly similar in the three other subregions, despite significant variations in the asset base and poverty. It is perhaps even more surprising that the relatively poor Bihar subregion had the lowest reported use of draft animals. This seems associated with the question of whether tractors and draft animals are complements or substitutes and the relative trade-offs between the utility and the cost of these two traction options. For instance, the maintenance cost of draft animals is relatively high in the densely populated Bihar subregion where tractors and draft animals are primarily substitutes, with farmers using one or the other. In contrast, in some of the relatively 'better-off' surveyed communities, tractors and draft animals are primarily complements. For instance, in the Meerut cluster, in the sugarcane belt of Uttar Pradesh, farmers used tractors primarily for tillage and used draft animals (male buffalo and bullocks) for hauling cane to the mill and interrow cultivation. The maintenance cost of draft animals in this area was kept in check by the widespread availability of sugarcane tops (Singh et al. 2007).

Although chemical fertilizer use is near-universal amongst farm households in the surveyed villages, the use of farmyard manure is still widespread (Table 41). However, despite widespread use, quantities actually applied to crops are limited due to availability constraints. Except for West Bengal, the livestock density in the surveyed villages generally averaged 1–2 cow equivalents per cultivated hectare (Table 33) which limited the total potential quantity of manure available. Still, the use of farmyard manure was reportedly highest in the northwest, and lowest in West Bengal (Table 41). The prevailing stall-feeding of large ruminants in the northwest facilitates the recovery of most of the dung produced, whereas in West Bengal grazing is more widespread (Table 40).

Table 41. Comparative indicators of external and livestock input use for crop production (% of households reporting use).

Subregion	Use of tractors	Use of draft animals	Use of chemical fertilizer	Use of farmyard manure
Trans-Gangetic Plains	89 b	31 ab	97	84 bc
Uttar Pradesh	90 b	37 bc	100	88 c
Bihar	88 b	10 a	100	64 ab
West Bengal	66 a	60 c	89	59 a
Mean	84	36	97	74
(sd, n, p)	(27,69,0.02)	(39,59,0.00)	(16,72,0.13)	(38,69,0.06)

Notes: Data preceding different letters differ significantly—Duncan multiple range test (significance level: 0.10), within column comparison.

Compounding the availability is the alternative use of dung as household fuel. In the surveyed communities, about half the annually collected dung was reportedly used as farmyard manure with the other half used as fuel (Table 42). The use of dung for biogas plants was uncommon. The relative use of dung as manure or fuel is seasonal, with its use as fuel in the dry season and as manure in the rainy season.

Dung is typically collected in open heaps in or near the homestead within the village perimeter. No composting was reported. Dung cakes are used as a year-round household fuel source and are produced manually mainly during the dry season so as to properly dry in the open. Their shape varies by region and they are generally stored in the open in elaborate stacks. Dung cakes are typically produced by women and used for both own household use and sale, the latter being an additional source of income for small farmers and landless households. The use of dung cakes at the household level is likely to vary depending on the availability of alternative fuel sources, but at the community level it was relatively similar across the subregions.

Assessing Crop-Livestock Interactions

The complementarities between crop and livestock production are often idealized and seen as building blocks for socioeconomic development and environmental sustainability. The complementarities

Table 42. Dung use (% of dung allocated to use).

Subregion	As fuel	As farmyard manure	Other
Trans-Gangetic Plains	40	58	2
Uttar Pradesh	45	54	1
Bihar	57	42	1
West Bengal	47	53	0
Mean	47	52	1
(sd, n, p)	(27,72,ns)	(27,72,ns)	(4,72,ns)

Note: ns: nonsignificant.

thereby reflect assumed, mutually beneficial interactions and synergies between crops, livestock and human livelihoods. The current study once more confirms the complementarities between crop and livestock production. A consistent finding across the IGP is that a few households are specialized in either crop or livestock production and integrated farm systems are the rule. The livestock (buffalo, cattle) component is thereby highly integrated with the crop (rice, wheat) component, albeit with distinct management for the two enterprises. However, the present study also questions the extent to which this is based on mutually beneficial crop-livestock interactions. Clearly, livestock production benefits from a widespread reliance on the use of crop residues, grasses, weeds, and other agricultural wastes for feed purposes. However, the beneficial return flows from livestock to crop production seem more limited. Traction services have largely been replaced with tractorization and the soil fertility maintenance function of farmyard manure, to a large extent, with chemical fertilizers, and thwarted by competing household fuel demands and limited availability per unit crop area. Over time and space, the intensification and commercialization of the agricultural systems have thereby weakened the crop-livestock interactions and increasingly decoupled the crop and livestock subsectors.

Combining crop and livestock production implies a more diverse livelihood portfolio and reduction in risk. The two enterprises also have different resource use patterns (particularly labor and cash flow) which imply complementarities and potential resource savings at the household level by allowing more efficient resource use. Farm income also becomes more regular. Proceeds from crop sales are highly seasonal and often realized once or twice a year, whereas proceeds from the sale of milk, meat, young stock, etc., can be more regular and more flexible. Financial interactions between the livestock and crop enterprises are reportedly important in the surveyed communities. Financial proceeds from livestock production are used to meet crop production expenses and vice versa. Livestock also provide an investment and accumulation opportunity. Livestock thus provide an insurance and financing function and display status (Moll 2005). Conversely, alternative risk-reducing mechanisms (e.g., assured irrigation or the assured cereal markets in the TGP), may reduce the importance of the insurance function of livestock and thus further dilute crop-livestock interactions.

The group meetings tended to highlight the importance of the crop and livestock enterprises in terms of contributing to household income and household consumption (staple, milk, fuel) and internal services (use of crop byproducts, manure, traction) and their complementarities in terms of labor use and more regular income. In terms of disadvantages, damaging of crops by free-roaming animals (including stray male cattle) was mentioned. Because of their religious status, cattle slaughter is prohibited in India except in the states of Kerala and Nagaland.

The surveyed communities in the IGP presented a range of crop-livestock integration. Compared to the other IGP subregions, crop-livestock interactions currently play a more prominent role in the West Bengal subregion, particularly the Medinipur and Malda clusters. In the other West Bengal (Nadia) cluster, crop-livestock interactions have declined with the intensification and commercialization of crop systems induced by its proximity to Calcutta. In contrast, the Meerut cluster in Western UP had relatively pronounced crop-livestock interactions, despite its relative proximity to Delhi. This was primarily linked to the widespread cultivation of sugarcane and the use of sugarcane tops as forage and the use of animal traction in sugarcane cultivation.

The crop-livestock interactions underpinned livelihood security in the IGP, but currently does not really drive any system change, and current interactions seem a reflection of subsistence and status quo. Yet, the level of integration has changed over time, particularly in the northern plains, as wheat-cattle systems were relatively interdependent in the pre-Green Revolution era. Indeed, we hypothesize that crop-livestock interactions played a significant role in shaping the current crop-livestock systems even in the upstream subregions. Particularly, the widespread substitution of buffalo for cattle in the upstream subregions seems to be associated with two interaction-related modifiers (in addition to the preference for higher-fat buffalo milk). First, animal traction was replaced with increased mechanization. This reduces the attractiveness of keeping cattle vis-à-vis buffalo. Indeed, the eroding role of draft bullocks in combination with sociocultural restriction of selling male cattle and increasing the availability of artificial insemination drastically reduces the value of male offspring of cattle, and inherently limits the accumulation of herd capital. In contrast, male buffalo can be sold for meat (primarily for export). Second, the advent of irrigation and consequent increase in cropping intensity have tilted the balance in favor of stall-feeding that favors buffalo (and crossbreds) over desi cattle.

Chapter 7 Discussion and Recommendations

Livelihood Security and Environmental Sustainability

Poverty in the IGP is the result of low levels of assets, combined with low and uncertain returns. The surveyed communities thereby show significant diversity in terms of livelihood security. Particularly striking is the Northwest-East divide of the IGP, with its implications for livelihood assets, livelihood strategies and crop-livestock interactions.

Livelihood security in the NW IGP

In the NW IGP the asset base and returns are relatively favorable. The livelihoods of landed households are quite comfortable, particularly when the farm is reasonably large, in view of the well-established irrigation systems and developed market and institutional infrastructure. Particularly, the rice-wheat system provides an attractive and stable income to the farm household with minimal risk. The secure and profitable system thrives having both limited market risk (assured market and prices) and production risk (secure irrigation). The inherent security and profitability also imply there is limited scope for crop diversification within the current context. Dairy buffalo, which use crop byproducts, add value to the crop production enterprise and provide a significant complementary income source, adding to the level and stability of household income and reduced seasonality and overall risk. However, compared to the eastern plains, the nonmarket functions of the livestock probably play a less-important role in livelihood strategies in the northwest, particularly in view of the relatively low risk of crop production plus the relatively good access to financial services. Even smallholders did relatively well in the NW IGP by integrating agricultural intensification and dairying with off-farm diversification.

The divergent management of the crop and livestock component is another striking feature, particularly in the northwest (Erenstein et al. 2007c). Crop production is largely intensified, with high external input use, high productivity, and high market integration. In contrast, livestock intensification seems lagging with the 'harvesting' of milk and sales of surplus milk. This strongly suggests that the incentives for livestock intensification have so far been less pronounced. On the one hand, the surveyed communities in the northwest thereby highlight the importance of market forces and irrigation for intensification and diversification and, on the other, they highlight the prominent role of livelihood security and risk aversion even in productive and commercial agricultural systems.

The livelihood security for those with an adequate asset base is in stark contrast to those households that lack such resources in the northwest. Some asset-poor households have benefited through permanent or employment options on large farms, but typically they have a poor bargaining position. Primarily reliant on their unskilled labor, their livelihood security is further undermined by the advent and widespread use of labor-saving technologies (mechanization and herbicides). The labor peaks associated with the widespread rice-wheat cultivation on relatively large farms have also resulted in a seasonal inflow of labor from the eastern plains, thereby depressing the wage of local labor and reportedly creating social problems.

Livelihood security in the Eastern IGP

The Eastern IGP presents a comparatively dismal picture. Costly and scarce irrigation, poor crop yields, and small and fragmented farm holdings all make farming less profitable, particularly for small farmers. Inequitable distribution of land implies that the few large farmers are relatively comfortable. Regional economic growth is slow, providing few employment

and diversification opportunities. Population growth is positive and leads to further fragmentation, keeping wage rates low. High dependence on rains for crop production, lack of institutional finance and veterinary and extension services add to the uncertainties of rural livelihoods. Poverty of all livelihood capital assets is endemic. Resource constraints encourage goat rearing and piggery as a supplementary income source for small farmers and landless households.

The smallholder farming systems in the eastern plains are more subsistence- than market-oriented, lacking secure irrigation services and prone to flooding and waterlogging. As a result, there are few opportunities for low-risk diversification of cropping and livestock and fewer opportunities for the landless to secure casual agricultural employment. Therefore, while the small herds and flocks of bovines and goats have added value, reduced risks and stabilized incomes through converting low-value crop residues to higher-value milk, live weight and dung, the contributions of these crop-livestock interactions to livelihoods have not allowed families to escape the apparent poverty web in which the majority are trapped. Dependence on livestock for income and employment was also said not to be attractive to the young generation because their year-round labor demands have reduced the mobility of this generation to pursue other livelihood options. A common refrain was the desire of the parent generation to equip their children to escape a farm-based livelihood. The surveyed communities reiterate that the poor in the IGP are highly heterogeneous, "ranging from the truly destitute who have nothing and at best manage to survive, to households that are building assets and accumulating small surpluses, well on their way to climbing out of poverty" (World Bank 2002:11).

Key determinants of livelihood security

The two key determinants that shape the contrasting livelihood security in the IGP are the asset base and the market opportunities that enable rural households to accumulate a surplus. In terms of assets, access to land is central to the security of rural livelihoods across the IGP. Indeed, poverty is highest and concentrated amongst the rural landless, predominantly agricultural laborers. The ability to produce surplus is closely associated with the farm size and its annual productivity, the latter largely determined by secure irrigation. The market opportunities are closely associated with market access (e.g., proximity to urban centers for dairy) and market infrastructure. Particularly, market opportunities for labor-intensive crops, dairying, and off-farm diversification can contribute to a relatively broad-based growth.

In terms of both the asset base and market opportunities, the NW IGP tends to be better off than the Eastern IGP. However, as highlighted in the subregional reports, there can still be significant variation within subregions. For instance, Western Bengal showed the prominent effects of proximity to Kolkata and the extension of irrigation facilities and advent of boro rice that increased the marketable rice surplus (Varma et al. 2007). In Bihar, isolated patches of crop diversification—the introduction of vegetables and commercial production of maize grain—indicated some potential for agricultural intensification, but high rates of interest for credit and weak agricultural R&D support inhibited risk-taking (Thorpe et al. 2007).

Environmental sustainability

A major threat to the current livelihood strategies is their environmental implications. Water management is a key concern throughout the IGP, albeit varying from overexploitation of groundwater in some areas (e.g., Erenstein et al. 2007c) to poor unreliable irrigation and the negative effects on productivity from flooding and waterlogging in others (e.g., Thorpe et al. 2007; Varma et al. 2007). With the continuing spread of private diesel-powered tube and shallow wells, declining water tables are likely to become more widespread and require urgent study to inform policy making and short- and medium-term action planning. The threat of consuming arsenic-contaminated groundwater is increasingly recognized in the eastern plains (Varma et al. 2007).

Another significant threat to the current livelihoods is the mining of soil fertility and organic matter. The management of organic matter is particularly problematic, with the largely one-way extractive flows from the field leading to depletion of the stocks of soil organic matter throughout the IGP, particularly in the eastern plains. The prevailing crop-residue management practices, intensive use of cereal residues, and limited application of farmyard manure imply that few organic residues remain in the field at the time of land preparation. Soil fertility is further undermined by unbalanced fertilizer use. In the northwest, the burning of crop (rice) residues during land preparation also contributes to significant pollution of air quality in both rural and urban areas in the region.

The high population density and still positive population growth exert considerable and increasing pressure on the already intensively used natural resource base, particularly in the eastern plains. For instance, the use and storage of dung cakes for household fuel extend across the IGP. But particularly in the eastern plains, household fuel sources seemed to be in short supply, suggesting an impending crisis in household fuel.

The dominance of agricultural activities in the IGP implies that the region is already characterized by its limited rangeland, forests, and biodiversity. More important perhaps is the need to maintain agricultural productivity in these high potential areas so as to reduce agricultural pressure on the fragile natural resources elsewhere. The advent of the virulent new stem rust for wheat (UG99) and global warming could thereby have major implications for the IGP and beyond.

Outlook and Constraints

Despite the contrasting scenarios throughout the IGP, the situation in the surveyed clusters appeared relatively stagnant and without any clear future direction. In the NW IGP there was limited incentive for change. The vested interests, including the landed households, seemed to have relinquished any major drive for change and to settle for the cosseted status quo, further reflecting the security of the current agricultural system. Yet the natural resource base seems stretched to the limit with no new major technological breakthrough in sight to propel these systems from their current plateau. The NW IGP thereby seems to be at the crossroads, where something has got to give way.

In the Eastern IGP, change was most needed in view of the prevalent poverty, but least obvious in view of the miscellaneous constraints hampering agricultural intensification and further diversification into agricultural and nonagricultural activities. The limited human capital and the social structure further undermine these options in climbing out of poverty. The extent and quality of public services provided thereby seem a constraint for future development. A striking example is the road infrastructure in the eastern plains, whose capacity and quality seem woefully inadequate to support the bourgeoning population and enable economic growth opportunities in urban and rural areas alike.

The prospects for the rural landless are particularly meager. Unskilled labor is their basic asset, but the prevailing wage rate is low and the value of that asset will continue to be eroded in view of continued population growth and limited growth in labor-intensive sectors. Indeed, finding sufficient employment was one of their pressing problems. The coping strategy of seasonal migration towards labor-deficit areas in the IGP is also threatened by the slowdown in agriculture and the advent of labor-saving technologies. Landless would benefit from better basic education to strengthen their human capital asset and bargaining position. Their limited access to other assets typically constrains their ability to diversify their livelihoods.

The current farm systems in the IGP are predominantly small-scale integrated crop-livestock systems and likely to remain so in the medium term. The few large landholdings however seem to move towards crop specialization, having the means to invest in mechanization and thereby circumvent bottlenecks in labor. Further specialization into commercial dairy is likely for those who have a potentially big enough milk enterprise and secured market access. Such specialization is more likely in the peri-urban interface. Such specialized dairies would also imply an increasing spatial separation between livestock production and feed production and further reliance on and development of crop-residue and fodder markets.

Agenda for Action

This report synthesizes the scoping studies in the four subregions of the IGP. Each scoping study has set out to present primary information from village-level surveys, to relate the information to secondary sources, and to draw some broad conclusions that address the interface of IGP's crop and livestock subsectors. Specifically, it has focused on the management of crop residues because of their importance as ruminant livestock feeds and their role in natural resource management. The intention was not to provide any definitive answers or recommendations, but rather to flag issues for research.

The scoping studies highlight the need for a more enabling environment for overall economic and human development in the IGP with two specific objectives: to enhance the human capital base and

skills through basic education; and to stimulate the economic growth of the secondary and tertiary sectors to absorb surplus labor from the primary sector and the rural landless. The scoping studies also call for a more enabling environment for agricultural development in the IGP including technologies and policy/institutions that are appropriate and integrated. These priorities for action apply throughout the IGP, and are even more urgent in the eastern plains where low productivity and poverty are endemic.

For these broad objectives to succeed, it is clear that a change in the R&D paradigm will be required. The change will involve a shift from a reductionist, plot/animal-level research to people-centered, participatory and holistic methods and to interdisciplinary and multi-institutional approaches.

Action Research Needs for IGP

The four scoping studies in the IGP highlight a set of specific research needs that cut across the subregions. These specific needs relate to the land use systems of the IGP and their crop, livestock and crop-livestock interaction components and include action research to:

- Understand and address the variation in land use systems and the resulting constraints and opportunities for diversification and intensification.
- Address key issues including community action and institutions for improved management of land, water and livestock resources and ways to increase market access for inputs (including knowledge) and outputs.
- Improve the productivity of the rice and wheat staple crops, including through identifying resource-conserving technologies and appropriate policies/institutions (including water pricing), while factoring in any trade-off effects on the feeding of crop residues to livestock; and, related to that investigate: (i) whether variation in rice, wheat, and maize varieties for fodder quality (nutritional value) is an avenue for increasing the available quantity and quality of crop residues for feeding goats, cattle, and buffalo; and (ii) the management of organic matter, particularly issues of crop biomass management impacting on the prevalent crop-livestock livelihood strategies of landed and landless households, taking account of the multiple functions of the crop residues (including fuel) and of the various livestock species within the household and the community.

Central to achieving the overall goals of improving livelihoods and more sustainably using natural resources in the IGP will be strengthening the client orientation and productivity of the agricultural R&D community and integrating technology and policy/institutions. Research on crop-livestock interaction can serve as a good entry point for that process.

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Annex 1

Socioeconomic and development indicators in the states of the Indo-Gangetic Plains.

Indicators		Year/Source	Punjab	Haryana	Uttar Pradesh	Bihar	West Bengal	All India
Population (10^6)		2001 (1)	24.4	21.1	166.2	83.0	80.2	1,029
Increase (%)		1991–2001(1)	20.1	28.4	25.9	28.6	17.8	21.6
Population density (per km^2)		2001 (3)	484	478	690	881	903	325
Rural population (%)		2001 (3)	66.1	71.1	79.2	89.5	72.0	72.2
Farming population (%)		2001 (3)	32	46	48	31	25	
Landless population (%)		2001 (2)	22	19	29	51	33	
Literacy	Male (%)	2001 (4)	76	79	70	60	78	76
	Female (%)	2001 (4)	64	56	43	34	60	54
Rural population below poverty line (%)		1999–2000 (1:9–10)	6.4	8.3	31.2	44.3	31.9	27.1
Share of agriculture in Gross State Domestic Product at 1993–94 prices (%)		2001–02 (1)	39	31	33	35	23	24
Per cap income at current prices		2002–03 (2)	26,000	26,600	10,300	6,000	18,800	18,900
% of households in income classes (Rs/month)	< Rs 3,000	2002–03 (2)	52.4	64.2	80.7	85.1	77.8	
	Rs 3,001–6,000		38.7	26.5	14.9	10.6	16.4	
	Rs 6,001–10,000		6.5	6.8	3.4	3.3	4.4	
	Rs 10,001–20,000		2.2	2.5	0.9	1.0	1.4	
	> Rs 20,000		0.1	Negligible	Negligible	Negligible	0.1	
Geographical area (10^3 ha)		2000–01 (3)	5,036	4,421	24,093	9,416	8,875	328,724
Cultivated area (10^3 ha)		2000–01 (3)	4,250	3,526	17,612	7,437	5,417	141,087
Area irrigated (%)		2000–01 (3)	95	83.9	72.8	48.7	43.5	39.1
Area irrigated by source (%)	Canal	2000–01 (3)	24	50	24	31	11	30
	Tube wells		76	50	69	55	53	40
	Others		0	0	7	14	36	30
Cropping Intensity (%)		2000–01 (3)	187	173	154	147	168	137
Average farm size (ha)		2000-01 (5)	4.03	2.32	0.83	0.58	0.82	1.41
No. of tractors (10^3)		2001–02 (3)	442	331	677	107	35	3,084
No. of pump sets energized (10^3)		2002 (4)	811	427	815	276	112	13,044
Expenditure by State Agricultural Uiversities (Rs 10^6)		2004–05 (4)	1,410	1,025	738	708	594	
Food grains	Area (10^6 ha)	2002–03 (1)	6.13	3.98	17.90	6.88	6.54	111.50
	%		5.5	3.6	16.1	6.2	5.9	100
	Production (10^6 t)		23.49	12.34	36.30	10.27	15.52	174.19
	%		13.5	7.1	20.8	5.9	8.9	100
Marketed share (%)	Rice	1999–2002(1)	96	91	74	68	55	70
	Wheat	1999–2002(1)	80	78	58	67	-	67
Fruits	Area (10^3 ha)	2002–03 (4)	40.5	31.9	280.3	294.8	152.2	3,787.9
	Production (10^3 t)		578	237	4,314	3,038	1,786	45,203
Vegetables	Area (10^6 ha)	2002–03 (4)	0.14	0.16	0.85	0.61	1.21	6.1
	Production (10^3 t)		2.3	2.1	15.8	8.3	17.4	84.8
Milk production (10^6 t)		2002–03 (1)	8.7	5.1	15.3	2.6	3.6	87.3
Egg production (10^9)		2002–03 (1)	3.5	1.2	0.8	0.7	2.8	40.2
Fish production (10^3 t)		2002–03 (1)	66	35	250	166	1,120	6,200
Dry fodder (10^6 t)		2002–03 (4)	29.4	18.9	80.8	15.6	21.6	377.7
Green fodder (10^6 t)		2002–03 (4)	25.5	19.0	35.8	1.3	1.9	503.1
Wet dung production (10^6 t)		1987 (4)	33.2	34.5	24.2	22.4	21.7	615.5
Electricity consumption for agriculture (%)		2001–02 (1)	27	42	20	23	7	25
Road length (km/100 km^2)		2000 (3)	104	59	53	19	56	45
Fertilizer use (kg/ha)		2003–04 (4)	184	167	127	81	122	90

Sources: (1) MoA 2004; (2) Business World 2005; (3) ESO 2004; (4) IASRI 2005; (5) MoA 2006.

Annex 2

Area, yield, and production of major crops in the states of the Indo-Gangetic Plains.

Crop	State	1974-75			2003-04		
		Area ('000 ha)	Production ('000 t)	Yield (kg/ha)	Area ('000 ha)	Production ('000 t)	Yield (kg/ha)
Wheat	Punjab	2,213	5,300	2,395	3,444	14,489	4,207
	Haryana	1,117	1,954	1,749	2,303	9,134	3,966
	Uttar Pradesh	6,152	7,176	1,164	9,150	25,567	2,794
	Bihar	1,478	2,000	1,353	2,119	3,778	1,783
	West Bengal	422	837	1,984	426	986	2,315
	All-India	18,010	24,104	1,338	26,581	72,108	2,713
Rice	Punjab	569	1,179	2,072	2,614	9,656	3,694
	Haryana	276	393	1,426	1,016	2,793	2,749
	Uttar Pradesh	4,530	3,523	778	5,952	13,012	2,187
	Bihar	5,228	4,540	868	3,557	5,393	1,516
	West Bengal	5,420	6,543	1,207	5,857	14,662	2,504
	All-India	37,889	39,579	1,045	42,496	88,284	2,077
Maize	Punjab	522	898	1,720	154	459	2,981
	Haryana	124	125	1,010	15	38	2,573
	Uttar Pradesh	1,394	827	593	947	1,319	1,392
	Bihar	881	572	650	607	1,440	2,374
	West Bengal	46	52	1,137	41	97	2,359
	All-India	5,863	5,559	948	7,322	14,929	2,039
Sugar-cane	Punjab	123	6,150	50,000	123	7,870	64,000
	Haryana	161	5,910	37,000	161	9,340	58,000
	Uttar Pradesh	1,492	61,479	41,000	2,030	112,754	56,000
	Bihar	141	5,568	40,000	103	4,222	41,000
	West Bengal	29	1,682	58,000	17	1,268	75,000
	All-India	2,894	144,289	50,000	3,995	236,176	59,000
Total Pulses	Punjab	328	245	746	48	48	824
	Haryana	781	374	479	196	149	740
	Uttar Pradesh	3,154	2,185	694	2,708	2,339	886
	Bihar	1,554	867	558	684	562	824
	West Bengal	682	376	550	252	30	840
	All-India	22,024	10,020	455	23,440	14,940	637
Total Oilseeds	Punjab	368	290	790	87	102	1,167
	Haryana	214	149	694	640	990	1,547
	Uttar Pradesh	3,784	1,927	509	1,140	928	814
	Bihar	296	132	446	149	125	842
	West Bengal	204	75	369	684	651	952
	All-India	17,313	9,152	529	23,700	25,290	1,067
Cotton	Punjab	547		373	452		414
	Haryana	246		311	526		372
	Uttar Pradesh	35		118			150
	Bihar	-		-	-		-
	West Bengal	-		-	-		-
	All-India				7,630		370

Source: MoA 2005.