Solidaridad network

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WHITE PAPER

LANDSCAPE APPROACH

LAND - WATER - COMMUNITY SECURITY

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PREFACE

This study on land-water-community security in the mid-Ganga Basin was rooted in concern over rapidly increasing pollution levels in the basin resulting in poor water quality in river Ganga. When we got deeper into the issue, we realized that there were many interdependent factors that were contributing to the degrading resource; including changes in cropping pattern, agricultural intensification, expanding industrial base and rapid urbanization. There was thus a felt need to understand the dynamics in the physical and the human resource interactions that was resulting in such precariousness. The team of researchers at TERI-SAS in collaboration with the team at Solidaridad Network thus decided to understand this dynamic and look not just at the water quantity and quality issues in the basin but also its inter-linkage with the changing land use practices and the socio-economic and socio-cultural conditions in the basin.

The landscape approach was best suited to explain the interactions between the physical and social environment and suggest suitable measures to holistically address the causes of degradation. This approach, aiming to allocate and manage land to achieve balanced socio-economic-ecological outcome, calls for recognition of multiple stakeholders, conflicting goals, and land use practices that affects natural resources. As many reports suggested, mid-Ganga basin was a witness to this pressure and consequent impact on the riverine resource system. Along the stretch several towns, industries and agricultural activities contribute to point and non-point sources of pollution. A general degradation in the river system was caused by riverside cash crop farming (example: sugarcane), indiscriminate sand/gravel mining, riverbed farming, unscientific fishing, open defecation etc. (CPCB, 2013). Rapid urbanization along the river banks was imposing additional pressure on the already degrading resources. In general, the nature of use of water resource had affected both the flow and the quality of water in the mid Ganga basin. The short and long term consequences of this impact would be felt both by the physical environment and the society.

Such nuancing required an in-depth analysis of the land and water uses and the process of allocation of these resources. This called for viewing the river (ecological) systems in consonance with the socio-cultural systems and understanding that development interventions and resource allocation decisions involve tradeoffs. For the purpose of this work, landscape was given a territorial dimension and encompassed a complex milieu of ecological (including soil, water, pastureland etc.) and socio-cultural sub-systems (such as human settlement, communication network and institutional arrangements). The study was carried out in three districts of Uttar

Pradesh on the right bank of the river Ganges. The major land use in these areas included agriculture and industrial belt interspersed with rural and urban settlements.

The objectives of the study included:

I. To understand the decadal change in land use and its implication on different biophysical aspects of resource at watershed level.
II. To understand the socio-economic and gender dynamics at village level and resultant pressure on resource systems
III. To understand the soil, water and crop linkages at village level
IV. To analyze the industry-resource (water) interlinkage and understand associated best practices

The study sites were selected on the basis of changing resource use practices and pressures. Data collection on socio-cultural aspects was done through semi-structured interviews with different stakeholders, key informant interviews, focused group discussions and other participatory techniques. Data on water quality and soil characteristics were collected in the form of soil and water samples from the field, which were also tested in the laboratory. Geospatial technology was used to understand the land use/land cover change and its impact on water resources. Soil and water analysis was carried out in parallel with study on cropping pattern, to understand soil-water-crop linkages.

The findings from geospatial analysis showed urban area replacing cultivated land over last one decade in Kanpur district leading to decline in groundwater recharge capability. Further loss in vegetated land for urban expansion may have serious implications on water resource. In Hardoi district and Mohammadi tehsil of Lakhimpur, there was substantial decrease in cultivated land and increase in total area under fallow/barren over last one decade. This has led to increase in runoff and decline in groundwater recharge potential.

The findings from socio-economic analysis in Hardoi revealed that most of the income was from farming but highly subject to risk due to lack of access to institutional credit, market institutions, storage infrastructure and a resultant low bargaining power. The villages had no functional institutions and therefore low levels of awareness and social capital. Strong discrimination was found in women's access to social, economic and political institutions. Women did not have any say in decisions pertaining to resources, like property, crop choices, savings and investment. Access to social infrastructure was better in Kanpur. Groundwater along with piped water was used for

drinking and CETP canal water was used for irrigation. Farmers using CETP water specified high use of pesticides but low use of fertilizers, attributing it to presence of heavy metals in water that gave “a lot of power”. Some respondents from village closer to the canal complained of health conditions like presence of intestinal worms and degeneration of limbs. Economically, the General and OBC category respondents were better off in terms of occupational diversity, land holding size, asset ownership and livestock holding. Access to storage infrastructure and market was poor. Thus, farmers had very low bargaining power. Institutionally, the villages did not seem very robust in ensuring access to good infrastructure or accountability mechanisms. Gender roles were also restricted to associating reproductive role with women and productive role with men. By their responsibilities, women came closest to the natural resources, but their role in managing natural resources was limited. They had no access to property; they were “missing” from institutions; and lacked a ‘voice’ even after affirmative steps through reservation.

Study of soil-water-crop interlinkage in Kanpur showed that the use of canal water in adjacent villages had led to increased levels of chromium in soil and plant roots and shoot. Since canal effluent flows from the combined effluent treatment plant (CETP), it has high salinity inspite of being mixed with treated domestic sewage effluent. Father from the canal, the soil and plants both exhibited low chromium content. Owing to this, the village had started growing flowers, clearly showing a linkage between water quality- soil conditions and cropping pattern. Though farmers in Hardoi had shifted to sugarcane cultivation, the soil nutrient balance did not seem to be too adversely affected. This could be because such shift is recent and at smaller scale. However, it is important to consider that this area of Hardoi is not served by Sharda canal and is entirely dependent on ground water. The surface water bodies had also dried up in absence of proper management. Therefore, in the absence of any artificial recharge facilities, this could be a cause of concern in future and impact productivity.

Consolidating the findings it could be said that landscape approach calls for reconciliation between the conservation and development objectives with the aim of balancing socio-economic and environmental outcomes in any geographical context. In the mid-Ganga basin under discussion, which is under multiple pressures due to agriculture, industrial and urban expansion, managing the multifunctionality along with sustainability is a vast challenge. The study has provided various recommendations using 10 parameters of the landscape approach. Some of the major recommendations include (1) development of green belt around Ganga in Kanpur, (ii) revival of existing water bodies and reduction in groundwater consumption to address water stress condition

that may develop in near future, (iii) in the tannery belt, pretreatment of effluent may be practiced before it reaches the CETP inlet, (iv) factoring the socio-economic vulnerabilities, livelihood diversification and backward and forward linkages for agriculture.

In the long run interventions require greater stakeholder engagement, effective governance structure and better institutional coordination. More specific decisions pertaining to resource need to address efficiency issues and institutional coordination. The sugar mill study is a case in point where they seem to be adopting a 'co-benefit' approach while working with the farmers, thus not just providing a market for produce but also promoting better resource management practices like mulching etc. The study has tried to amalgamate various considerations through the landscape principles that is explained in the report.

We hope the readers will find this report insightful and of use in incorporating various recommendations to address the multi-dimensionality in landscape planning.

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EXECUTIVE SUMMARY

Introducing landscape approach

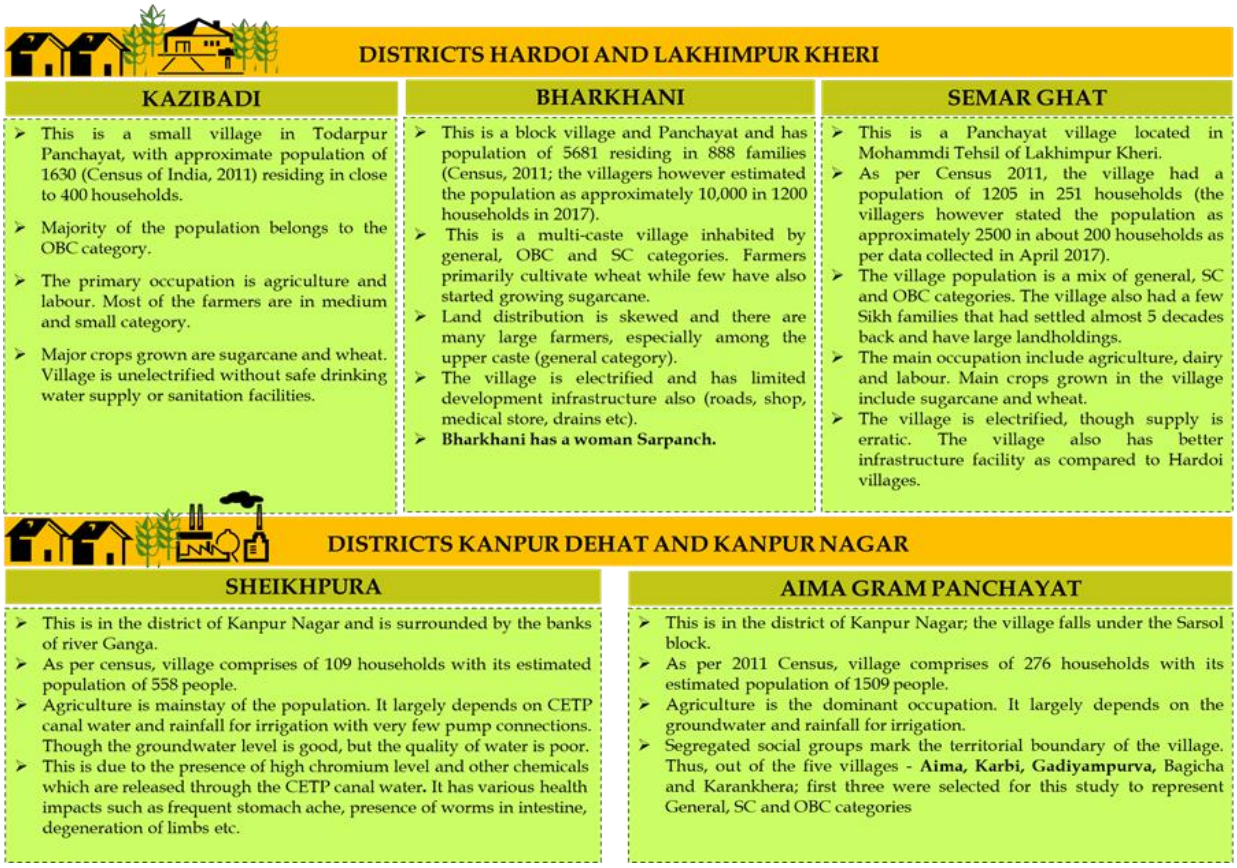
The *landscape approach* aims to integrate policy and practice for multiple land uses, within a given area, to ensure equitable and sustainable use of land while strengthening measures to mitigate and adapt to climate change (Scherr et al. 2012; Milder et al. 2012; Sayer et al. 2013; Harvey et al. 2014). It also aims at balancing competing demands on land through the implementation of adaptive and integrated management systems. These include not only the physical characteristic features of the landscape itself, but all the internal and external socio-economic and socio- political drivers that affect land use, particularly related to conservation, forestry and agriculture (Sayer et al. 2013). **In short, landscape approach seeks to address the increasingly complex and widespread environmental, social and political challenges that transcend traditional management boundaries (Reed et al. 2014).**

Why landscape approach in mid- Gangetic belt of UP: Rationale for the study

The landscape approach, aiming to allocate and manage land to achieve balanced socioeconomic-ecological outcome, calls for recognition of multiple stakeholders, conflicting goals, and land use practices that have implications for the physical environment, habitat and natural resources. The mid-ganga basin in Uttar Pradesh is witness to this pressure and consequent impact on the riverine resource system. The river in the middle parts largely entering the plains and supporting intense agricultural activities through canal systems impacts the flow downstream. Along the stretch several towns, industries and agricultural activities contribute to point and non-point sources of pollution. A general degradation in the river system is caused by riverside cash crop farming (example: sugarcane), indiscriminate sand/gravel mining, riverbed farming, unscientific fishing, open defecation etc. (CPCB, 2013). Rapid urbanization along the river banks is imposing additional pressure on the already degrading resources. In general, the nature of use of water resource has affected both the flow and the quality of water in the mid Ganga basin. The short and long-term consequences of this impact shall be felt both by the physical environment and the society and is of great significance for this densely populated state where almost 40 percent of the population is below the poverty line.

Aim of the study

The study helps to embed the landscape approach into river basin management. It suggests that



planning for a robust socio-ecological system requires that resource decisions (and consequent tradeoffs) be based on sound principles of equity, efficiency and participation while balancing these with ecological principles such as resilience. **The study was conducted in the two districts of mid-Gangetic plain i.e., Hardoi, Lakhimpur Kheri and Kanpur.** The specific objectives are:

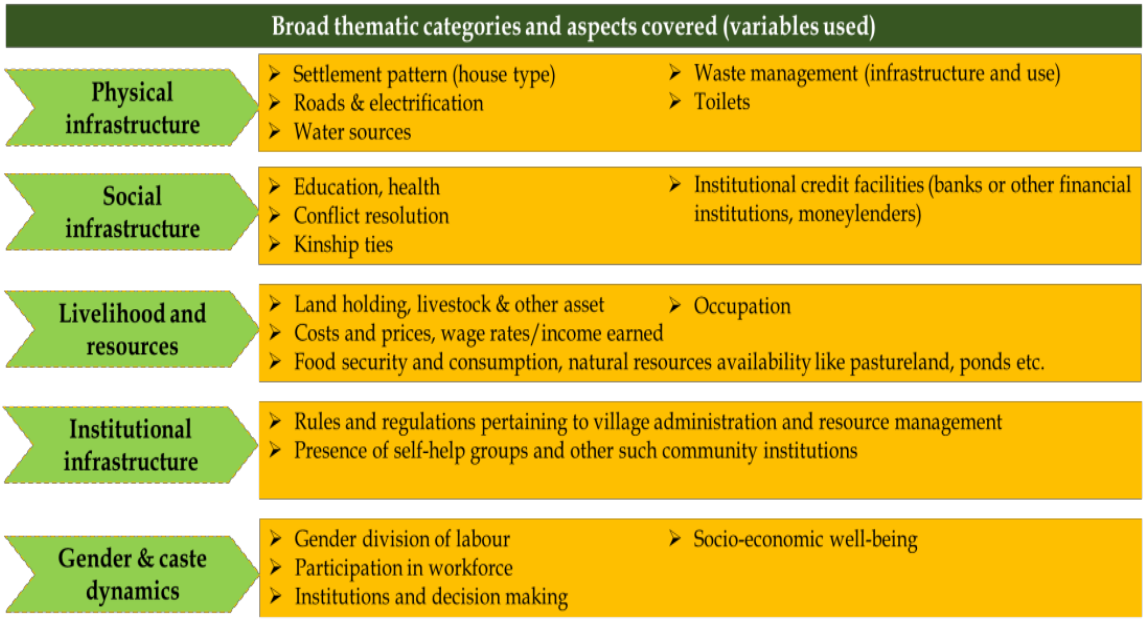
- To understand the decadal change in land use and its implication on different physical components such as evapotranspiration and groundwater recharge at watershed level.
- To understand the socio-economic and gender dynamics at village level and resultant pressure on resource systems
- To understand the soil, water and crop linkages at village level
- To analyze the industry-resource (water) inter-linkages and understand best practices

Methodology & findings

I. Land use/land cover change and its impact on existing water resource

Industrial belt	Sugarcane belt
➢ In Kanpur district, there has been increase in urban area and decline in cultivated land over last one decade. Most of the industrial expansion has occurred near Kanpur city leading to increase in urban area (3160 ha) over the last 10 years. These changes have occurred mostly on the land used earlier for either agriculture/pasture activities or were left barren/fallow. ➢ Most of the decline in cultivated area are the lands where Rabi and Kharif crops were grown. However, there has been an increase in summer (Zaid crop) which could be due to increase in the number of tube wells in the area. ➢ The overall loss in vegetated land for urban expansion may have serious implications on water resource due to decline in groundwater recharge capability of the area. This was also found in the hydrological parameters estimated using Soil Water Assessment Tool (SWAT) model. There has been increase in surface water run- off and decrease in ground water recharge in one watershed delineated under this study. Importantly, the decline in groundwater could have serious impact if the trend continues, as this is the main source for irrigation amounting to 74% in the Kanpur Nagar (DPC, 2008).	➢ In Hardoi district and Mohammadi tehsil of Lakhimpur, there has been substantial decrease (almost three times) in cultivated land (mostly Rabi and Kharif crop) and increase in total area under fallow/barren over last one decade. ➢ Most of these transitions have occurred in the western part of Hardoi that lack proper canal network and groundwater resources. **This study area has three watersheds: two wet and one dry watershed.** ➢ The dry watershed lies in western side of the Hardoi district. The hydrological parameters estimated using SWAT model suggest relative increase in the runoff potential and decline in groundwater recharge in the three watersheds. These changes in surface run off and groundwater recharge potential could be attributed to the increase in fallow land and decline in vegetation cover in this region.

The analysis was carried out using remotely sensed data (30-meter spatial resolution) for two-time steps (decadal data for three seasons), topography, soil and meteorological variables for the two study sites (industrial belt of Kanpur and sugarcane belt of Hardoi and Mohammadi). The daily meteorological data from 2000-2016 were used for the analysis.



II. Socio-economic and gender analysis

Mixed method approach was used to collect data on socio-economic dynamics and gender aspects. **Primary data** was collected using short surveys, semi-structured interviews, PRA techniques, focus-group discussions and non-participant observation. Expert interviews included interview with the CETP officials, irrigation department officials, officials from the sugar mill and the village sarpanch. **Secondary data** included Census data, Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) reports on water quality issues in Ganga, study reports etc. Purposive sampling was done to categorize the respondents on dimensions of occupation, caste and gender. Data was analyzed based on occupational categories to understand the community resource interactions and institutional dynamics. Gender dynamics and aspects of gender-resource interaction were captured separately.

HARDOI

- The **physical infrastructure** was poorly developed, with some areas still being unelectrified; most areas lacking basic sanitation and waste management facilities; poor connectivity to towns and inadequate access to market infrastructure. Groundwater was used for domestic (self-installed handpumps) as well as agricultural purposes. While the water levels had declined only a few respondents complained of declining quality, mostly felt through colour and taste. Caste based analysis revealed that the SC community lacked access to basic infrastructure as

compared to OBC and General category members.

- With respect to **social infrastructure**, the villages suffered from poor education levels, poor access to health institutions, low social capital and high caste discrimination. Economically the General caste farmers were better off with larger land holdings, followed by OBC and SC (who were most deprived). The average annual income from farming was approximately INR 1,67,769. However, this was subject to the land holding of the farmer. The input cost per acre for wheat and sugarcane was INR 4895 and INR 17500 respectively. Total revenue for wheat and sugarcane per acre was INR 17500 and INR 94500 respectively. However, farmers preferred to grow a combination of wheat and sugarcane for reasons of food security.
- Livestock holding was more like a risk measure except in Semraghat where larger number of livestock yielded higher income to upper caste farmers. Savings was not a common habit. Almost 60% of the farmers availed loans for productive purposes but only a mere 19% had crop insurance**. Overall, most of the income was from farming but highly subject to risk and lack of access to institutional credit, market institutions, storage infrastructure and a resultant low bargaining power. The villages had no functional institutions and therefore low levels of awareness and social capital**. Panchayat was not strong and therefore police was resorted to solve even minor conflicts in the village.
- In Hardoi, **strong discrimination was found in women's access to social, economic and political institutions**. There was strong gender stereotyping where women were restricted to reproductive roles and men associated with productive roles. Concepts of women's access to space and freedom of choice were alien. Most of the women were uneducated and faced restricted participation in workforce and market institutions. There was no tenurial security and inheritance followed patrilineal systems.
- **Decisions pertaining to education of children, household expenditure, marriage and family planning were taken jointly by male and female members of the households**. However, **women did not have any say in decisions pertaining to resources, like property, crop choices, savings and investment**. While women found very little space in decision making role at the household level, the representation and participation in village governance was dismal. Only one village (Barkhani) had a woman Sarpanch. However, the functional office was held by her husband. The participation was lowest among the SC member, who also faced severe caste discrimination.

KANPUR

- The **physical infrastructure** but again highly differentiated in terms of caste dynamics.
- Access to **social infrastructure** was better in Kanpur, however, incidence of disease was common. This included chronic diseases like arthritis, tuberculosis, diabetes, filaria, anemia, joint pain, blood pressure irregularities and fistula. Other common ailments included diarrhea, fever, hepatitis, intestinal worm, kidney stone, chicken pox and typhoid. Respondents preferred private facilities to public owing to better infrastructure. **Groundwater was the common source for drinking and irrigation in Aima as compared to Sheikhpura that had access to piped water for drinking and CETP canal water for irrigation.** In Sheikhpura, respondents faced health conditions like presence of worms in intestine, and degeneration of limbs. Economically, the General and OBC category respondents were better off in terms of occupational diversity, land holding size, asset ownership and livestock holding.
- Agriculture was the primary occupation for General category farmers while OBC and SC categories practiced subsistence farming and supported their income through labour and other activities. The major crops grown in the villages were wheat, *jowar, barsheen* and roses. **Farmers in Sheikhpura specified high use of pesticides but low use of fertilizers, attributing it to the presence of heavy metals in water that gave "*a lot of power*". Access to storage infrastructure and market was poor. Thus, farmers had very low bargaining power.** The youth did not show interest in farming due to low profitability and preferred to work in private or government sector. In Aima, a few farmers were said to have sold land to tannery owners (perceiving the upcoming tannery cluster close to the village).
- Livestock provided a steady source of income but there was no organized market for sale of milk. Although, all the respondents had bank account, savings habit was again not very common. Farmers had access to banks and used Kisan Credit Cards to borrow money for agriculture purposes. **Institutionally, the villages did not seem very robust in ensuring access to good infrastructure or accountability mechanisms** (though the Aima Sarpanch took lot of credit in construction of toilets).
- **Gender roles were also restricted to associating reproductive role with women and productive role with men.** Women were mainly responsible for tasks like cooking, cleaning, fetching water, taking care of animals and other domestic chores. They could voice their opinions in matters like savings and expenditures. However, in most matters like family planning, education, marriage, financial planning and crop choice, women were not able to take decisions. All agricultural related tasks, market transactions, decisions pertaining to farming

and decisions pertaining to property were in the realm of the male members**. By their responsibilities, women came closest to the natural resources, but their role in managing natural resources was limited**. They had no access to property; they were "missing" from institutions; and lacked a 'voice' even after affirmative steps through reservation.

- The study in Aima GP found that despite a woman Sarpanch, **the presence of women in institutions was rare**. This was an extension of gender norms that were fixed at household and community level. As a result, women themselves had started perceiving their insignificance in institutional matters, often labeling it as "*a man's business*". In absence of sufficient numbers, even those women who were interested in attending meetings were unable to participate. The study could not see active involvement of women in community level decisions. Their presence only assumed significance during elections. Women in Sheikhpura were relatively more exposed, yet their mobility and decision spheres were limited. They could only visit the market and other town facilities in the company of a male family member. Such discrimination manifested in their educational and economic status.

III. Soil Water Crop Linkages

It is well known that different agro-ecological zones have diverse types of soil and nutrients. They are also climatologically different and support different vegetation and crops. It is thus essential to select the right crop for the area, to optimize the crop yield and crop water requirements. To understand soil-water-crop linkages, soil analysis, water analysis and crops grown were studied.

The use of canal water in Sheikhpura village of Kanpur district has led to increased levels of chromium in soil and, plant roots and shoot. Since canal effluent flows from the combined effluent treatment plant (CETP), though it is mixed with treated domestic sewage effluent, it has high salinity (it is very challenging to reduce salinity of tannery effluent). As we move away from the immediate vicinity of the canal, the soil and plants both exhibit low chromium content. Owing to this, the village has started growing flowers, clearly showing a linkage between water quality- soil condition and cropping pattern.

- High concentration of chromium is observed in soil samples taken from farms close to the canal.
- Elevated level of calcium and sodium is directly responsible for introducing alkalinity in the soil.

- Chloride concentration at various sites indicates towards the saline nature of soil, adjacent to the canal.
- Presence of chromium could be seen in all the plant samples.
- Semi-submerged plant has high chromium content.

Though farmers in Hardoi have shifted to sugarcane cultivation, the soil nutrient balance does not seem to be too adversely affected. This could be because such shift is recent and at smaller scale. However, it is important to consider that this area of Hardoi is not served by Sharda canal and is entirely dependent on ground water. The surface water bodies have also dried up in absence of proper management. Therefore, in the absence of any artificial recharge facilities, this could be a cause of concern in future and impact productivity. The following analyses were drawn from the soil, water and plant sample tests.

- Lack of high values for NPK contents indicates that most of the nutrients have been used up during growth period as the soil samples were taken after harvesting. Therefore, soil is healthy with low electrical conductivity.
- No overuse of fertilizers was seen in these 4 villages, which is also seen from the test results of soil organic carbon content.
- The ground water test results show that water is of reasonably excellent quality as per the test parameter which are below standard limits. However, wherever the bore wells are old, not maintained well, rusting has resulted. This is reflected in the iron content of water
- The water balance in these watersheds will show a negative result if ground water is used continuously without efficient ground water recharge facilities.

Conclusion & recommendations

Landscape approach calls for reconciliation between the conservation and development objectives with the aim of balancing socio-economic and environmental outcomes in any geographical context. In the mid-Ganga context under discussion, which is under twin pressures from agriculture and industrial and urban expansion, managing the multi-functionality along with sustainability is a vast challenge. The land use and soil and water analysis in this region showed several trends like: shrinking green cover; decline in water bodies and ground water table; chromium and salinity

problems in canal water that is used for irrigation; concern with water balance in watersheds in future within the current scenario of water use and management.

- ***Land use/land cover change and its impact on existing water resource***

The land use/ land cover change analysis of the region suggests that the different transitions have a significant impact on the current water resources. In both industrial belt as well as sugarcane belt there has been increase in surface run off and decline in ground water recharge due to decline in total vegetated cover. **Therefore, there is need to put effort in the direction of development of green belt around Ganga.**

Specifically, in Kanpur district, there has been increase in urban area and decline in cultivated land over last one decade. The overall loss in vegetated land for urban expansion has led to decline in groundwater recharge capability of the area. Although currently not so significant, but the increase in surface run-off and decline in ground water recharge, if continued, could have serious impact on agricultural activities where groundwater is the main source for irrigation. The study also shows that there has been decline in the groundwater table due to withdrawal for irrigation in absence of canal network in the area and industrial use (around 400 leather tanning industries withdraw groundwater for their processing operations).

In Hardoi district and Mohammadi tehsil of Lakhimpur, most of the land use/land cover transition has occurred in the western part of the region that lack proper canal network and groundwater resources. Loss of vegetated cover and increase in fallow land in the study area has led to reduction in soil infiltration capability. Thus, there is an increase in the runoff potential and decline in the groundwater recharge in all three watersheds. The study also shows a decline in the water bodies that were present in the southern tehsil of Hardoi district. Therefore, an extension of the canal in the western part and the revival of water bodies could be considered in this region.

- ***Soil water crop linkages***

In Kanpur, the study showed an increased level of chromium in soil, plant roots and shoots adjacent to CETP canal. As one moves away from the immediate vicinity of the canal, the soil and plants both exhibit low chromium content. This has enabled the villages to grow flowers, clearly showing a linkage between water quality-soil conditions and cropping patterns.

Both chromium and salinity problems in the canal water flowing from CETP are closely linked to industrial practices. While the CETP capacity has not been enhanced, there has been unregulated increase in the number of tanneries. Removal of chemicals used in the tanning processes after

processing of hide is also a major challenge. **Therefore, it is recommended that by following best practices as shown in the Kanpur tannery case study, pretreatment of effluent may be practiced before it reaches the CETP inlet.**

However, in Hardoi the cropping pattern in the villages is gradually changing to include sugarcane cultivation as the neighboring sugar mills provide a ready market for the farmer's produce. **Since sugarcane cultivation requires intensive irrigation, more groundwater is extracted.** The results from various soil tests, including electrical conductivity and organic content analyses reveal that the soil is in good health though the water consumption is high. The study area fell under a semi-arid zone, **it is recommended to revive existing water bodies and reduce groundwater consumption to address water stress condition that may develop in near future.**

Though the farmers in Hardoi have shifted to sugarcane cultivation, the soil nutrient balance does not seem to be too adversely affected. This could be because such shift is recent and at smaller scale. However, it is important to consider that this area of Hardoi is not served by Sharda canal and is entirely dependent on ground water. The surface water bodies have also dried up in absence of proper management. Therefore, in the absence of any artificial recharge facilities, this could be a cause of concern in future and impact productivity.

- ***Community resource interactions***

The socio-economic and institutional analysis added complexities to the above findings and suggests that given these ecological trends, if the institutional intermediation does not address the socio-economic vulnerabilities, it will lead to further marginalization of certain communities and enhance resource degradation. **The parameters for micro/village level analysis included livelihood sources and income, food and water availability, asset holding, agricultural practices and backward and forward linkages, settlement type, sanitation and waste management facilities, health/health infrastructure, education, institutional opportunities and participation, gender roles and women's inclusion and resource management practices.**

The findings from Hardoi and Mohammadi tehsil of Lakhimpur showed that most of the income was from farming but it was highly subject to risks in absence of institutional credit, market institutions, storage infrastructure and resultant low bargaining power. The major crops grown in this area included wheat and sugarcane; but there was greater willingness to shift to sugarcane due to assured market and higher prices. This would benefit the farmers but concerns like lack of irrigation facilities, groundwater abstraction cost, energy prices, institutional credit requirements and weather risks might enable the better off farmers to gain in the long run. In absence of

appropriate institutions, resource sustainability would be threatened by declining vegetative cover and diversity, dying surface water bodies, groundwater abstraction rate, recharge rate and energy subsidies. The study also showed that the socio-economic status was strongly influenced by caste and gender dimensions. Thus, land distribution was skewed in favor of the General and OBC categories while women did not have property rights. Institutions were weak and participation in institutions was nominal, particularly for the lower caste groups. The Panchayat was not active and thus even minor village disputes were taken to the police. Women were mostly uneducated and faced restricted participation in workforce, market and political institutions. Their role in decision making at household level was meagre and faded at community level. Thus, even though they were closest to the resource albeit in a nurturing role, they were "absent" from the community and resource based institutions. Social infrastructure was poor as studied through literacy status, awareness levels, access to health institutions, and social capital. The study did not locate any intervention through civil society organizations in any of these realms.

The study in Kanpur showed that the area was better endowed in terms of physical infrastructure but ridden with complex caste dynamics. This was reflected in various dimensions of economic well-being, where the General and the OBC categories were better off in terms of occupational diversity, land holding size, asset ownership, and livestock holding. Agriculture was primary occupation for General category farmers, while others supported their income from other sources like labour, employment in tanneries and other unorganized units. Crop diversity was noticeable where farmers were also engaged in floriculture (particularly roses) along with regular crops like wheat and *jowar.* Yet, agriculture remained mostly of subsistence nature due to lack of backward and forward linkages. In absence of storage infrastructure and formal marketing linkages, farmers had low bargaining power. In addition to agriculture, livestock rearing also yielded a steady income but in absence of organized market for sale of milk and institutional support, this remained as a subsidiary source of income only. Unlike Hardoi and Lakhimpur Kheri, access to formal financial institution was better but savings and investment habit seemed lacking, even amongst those with steady source of income. Resource management practices and institutional support for the same could result in not just scarcity in future but further socio-economic vulnerability. In Aima, groundwater was used for drinking and irrigation purposes. While water table was reportedly receding and issues of quality surfaced, there were perceptible caste based differences where the high-income households could address quality issues by abstracting 'sweet' water from 150 to 180 feet while low income groups could not. Surface water sources were filled, eutrophied or dried up due to mismanagement. In Sheikhpura, farmers used CETP canal water for irrigation. They reported

using less fertilizer owing to the presence of heavy metals in water that gave 'a lot of power', but used more pesticides since the crops were prone to pest attacks. While incidence of both chronic and common ailments was common to both areas, there was a perceived correlation (which could not be statistically verified) between canal water and health conditions in Sheikhpura.

The access to social infrastructure (in terms of schools, markets, institutional linkages etc.) was better than Hardoi and Lakhimpur Kheri, yet institutionally the study villages did not seem robust as reflected through participation rate, accountability mechanisms and existing social capital. Women came closest to the natural resources, but their role in managing natural resources was limited. They had no access to property; they were 'missing' from institutions; and lacked a 'voice' even after affirmative steps through reservation. The social set up was so replete with gender stereotypes that women themselves had started perceiving their insignificance in institutional matters, often labeling it as 'a man's business'. The study could not see active involvement of women in community level decisions.

Overall, the socio-economic and gender analysis at the village level, with reference to natural resources (specifically water resource) suggests that the development planning in the region has not adequately considered the socio-economic vulnerability of the local communities and therefore decisions pertaining to trade-offs prioritize certain land use over 'not so productive' use (like agriculture in many places). Agriculture itself is highly politicized agenda in the state, whereby, certain sections 'capture' the subsidized resource access (state has free electricity in many areas; there is no regulation pertaining to groundwater use; procedure for institutional credit is unclear); while others still await even basic irrigation and credit requirements. In Kanpur, some of the farmers have also sold land preempting industrial sector growth. Considering low productivity and absence of jobs, the youth are willing to engage in other occupations and migrate to the city. This is indicative of the larger trend where we also see expansion of the urban sprawls and declining green cover.

The overall scenario suggests that the resource governance considerations need to factor the socio-economic vulnerabilities, livelihood diversification and backward and forward linkages for agriculture. In the long run inventions require greater stakeholder engagement, effective governance structure and better institutional coordination. More specific decisions pertaining to resource need to address efficiency issues and institutional coordination. The sugar mill study is a case in point where they seem to be adopting a 'co-benefit' approach while working with the farmers, thus not just providing a market for produce but also promoting better resource management practices like mulching etc. The study of tannery suggests techno-political

interventions with a mix of better treatment facilities and stricter regulations and enforcement mechanisms. The study has tried to amalgamate various considerations through the landscape principles that is illustrated in a matrix form (with broad and specific recommendations).

PRINCIPLE 1 & 2: RECOMMENDATIONS	
Continual learning and adaptive management	***Broad Recommendations*** ➢ Changes in landscape attributes (ecological, land use and socio-economic changes) must inform decision-making. ➢ Dynamic interactions across scale to foster new understanding and knowledge which become a basis for revised strategies. ***Specific Recommendations*** ➢ Continuous research to enhance sustainable production (particularly sugarcane) and to suggest crop rotation to maintain the soil health. ➢ Rejuvenation of water bodies which shall maintain water balance in the area. ➢ Capacity building of government and other staff on best practices in agriculture under changing soil and water conditions
Common concern entry point	***Broad Recommendations:*** ➢ Understanding & accepting different stakeholder interest, diverse values & beliefs. ➢ Adopt socio-ecological approach to address socio-economic vulnerabilities and resource degradation ***Specific Recommendations:*** ➢ Address water demand and management issues through extending/reviving canal networks in the south-western side; strengthening ground water management with allocation system; recharge through abandoned wells ➢ Extend infrastructure and institutional support for farming (reference to storage facility, institutional credit and market linkages could be an excellent entry point to sustainable farming technique adoption among farmers) ➢ Initiate interventions on allied livelihood options (opportunity for animal husbandry-by taking care of breed improvement, veterinary services, marketing and pricing aspects).

PRINCIPLE 3,4 & 5: RECOMMENDATIONS	
Multiple scale	***Broad recommendations***: ➢ Cross-scale participatory planning; inclusion of independent experts, organizations and local participants that can facilitate exchange of learnings ➢ Spatial-temporal mapping to capture the changes in natural resource and adapt planning in accordance with resource status. ➢ Development of 'bottom- up' community intervention strategies to improve land use practices ***Specific recommendations:*** ➢ Spatial mapping using multiple resolution earth observation dataset (few centimeters to few kilometers spatial resolution) ➢ Water allocation must be decided at each level (village, panchayat/municipality and industry) and collectively as well ➢ Creating awareness and including citizens in resource monitoring and planning
Multi functionality	***Broad recommendations:*** ➢ Change in vision on agriculture from 'cultivated landscapes' to multi-valued socio-ecological units/multi-functional socio-ecosystems ➢ Proper assessment and valuation of ecosystem services at landscape level (including water, land, vegetation) to plan for better risk diversification ➢ Building a green corridor along the river Ganges at Kanpur, along with decentralized treatment facilities. ***Specific recommendations:*** ➢ The potential of floriculture and agro-forestry remains unexplored- this could be taken up to support household income. ➢ Diversify from pure farm based livelihood system to allied and non-farm occupation (like livestock rearing, small enterprise development) ➢ Quality of treated tannery effluent, which is used for agriculture, needs to be improved and its health impacts must be properly assessed ➢ Continuous monitoring and assessment of crop productivity (particularly sugarcane) to improve crop yield through proper management rather than being focused on cultivated area expansion.
Multi stakeholder	***Broad recommendations:*** ➢ An area/landscape planning approach that brings together all stakeholders and mobilizes resources ➢ Create multi-stakeholder dialogue platforms that brings together

	stakeholders ***Specific recommendations***: ➢ ***Kanpur:*** Include Panchayat members (with representation from all caste groups), Kanpur Nagar Nigam officials, tannery owners and CETP officials in seasonal water allocation and management planning ➢ ***Hardoi:*** Include Panchayat members (with representation from all caste groups), Block Development official, Sugarcane commissioner, Sugar mill owners, Irrigation Department in seasonal water allocation and management planning ➢ Create local institutions with active involvement of NGOs/CSOs to generate awareness on soil and water quality, build capacity for resource monitoring and management and ensure equitable resource allocation.

PRINCIPLE 6, 7 & 8: RECOMMENDATIONS	
Negotiated and transparent change logic	***Broad recommendations:*** ➢ Need to generate higher social capital; better accountability mechanisms; higher transparency in functioning of state and non-state units ➢ Institutional measures more important- stricter real-time monitoring framework linking it to graduated sanctions (this must be a participatory effort) ***Specific recommendations:*** ➢ Capacity building of farmers and other stakeholders through regular trainings and workshops, to understand the resource condition, trends and involved in regular monitoring of resource ➢ Improving governance by clear accountability mechanisms; ensuring transparency in projects and planning; grievance redressal mechanisms to be developed with proper access rules.
Clarification of rights and responsibilities	***Broad recommendations:*** ➢ Creating a state level autonomous institution that becomes the nodal agency for coordination, planning, monitoring, compliance and dispute resolution. The scope for planning for this agency should be at a watershed scale. ➢ It becomes the mandate of this institution to consult all stakeholders (including local institutions), assess and prioritize demands based on resource condition and maintain a centralized database which is also freely accessible to the public. ➢ This autonomous institution can create sub-units for enforcement and

	monitoring at district/block or other levels, as required. ➢ Clear tenurial rights, including focus on women's property rights ***Specific recommendations:*** ➢ Well-defined resource and institutional boundaries- ensure that every person/institution has clarity on his/her rights and responsibilities ➢ Well-defined property rights with equal entitlement for male and female members of the household. ➢ Considering close interaction of women with natural resources, stress on greater women membership and involvement in village institutions and decision making
Participatory and user-friendly monitoring	***Broad recommendations:*** ➢ Local stakeholders and government agencies can learn and adapt together ➢ Recognizing validity of different knowledge systems- Collecting and managing data from multiple sources that can be integrated and information thus created can be used by various stakeholders ➢ Developing citizen science based approach for continuous resource monitoring and adaptive planning ***Specific recommendations:*** ➢ Creating mobile app which can be used by citizens to provide data at appropriate scales ➢ Capacity building amongst stakeholders to monitor and interpret water and soil quality parameters and adapt land use practices ➢ Affirmative steps to include villagers and women in decision making

PRINCIPLE 9 & 10: RECOMMENDATIONS	
Resilience	***Broad recommendations:*** ➢ Ecological resilience ➢ Maintaining soil and water health through active monitoring and restoration mechanisms ➢ Devising a landscape level geo-spatial framework for continuous annual scale monitoring of general land use, crop patterns and water resources with threshold based alert systems ➢ Community resilience: ➢ Enabling risk diversification mechanisms through livelihood interventions ➢ Ensuring backward and forward linkages where farming is practiced ***Specific recommendations:***

	➢ Considering semi-arid characteristics in Hardoi, preservation of natural soil nutrient levels is crucial to ensure resilience ➢ Use of mulch, manure from sugar mills, produced as by product in sugar mills to maintain sustainable soil moisture and nutrient levels. ➢ Rejuvenation/restoration of dried up surface water bodies to ensure continuous water supply ➢ Active consideration of groundwater recharge to maintain sustainable ground water levels ➢ Regular monitoring of water and soil quality and impact of effluents on crops and health of farmers ➢ Regular monitoring of cropping pattern and providing suggestion on right mix of crops ➢ Floriculture in Kanpur region should be encouraged considering high salinity and presence of chromium in effluent canal water that is used for agriculture ➢ Proactive intervention in alternative livelihood sources (allied and non-farm activities- for example: livestock rearing, small enterprise development) to support household income levels ➢ Promote self-help groups and other local institutional interventions to mobilize farmers and promote collective action ➢ Ensure better risk preparedness among women members (through education, capacity building and property rights)
Strengthened stakeholder capability	***Broad recommendations:*** ➢ Strengthened stakeholder (including local institutions) capacity for participatory resource mapping, data assimilation and database management ➢ Need to increase literacy level and educate farmers on resource use efficiency ➢ Active education programmes and skill building particularly among the youth groups to enhance employability ***Specific recommendations:*** ➢ Skill training, capacity building among different government and local institutions on resource management, monitoring and citizen science approaches ➢ Enable handholding to small tanneries and industrial units for decentralized waste treatment facilities ➢ Encourage local innovations and development of 'bottom- top' community intervention strategies to improve land use practices ➢ Awareness strategies for water conservation. Educating citizens on depleting soil and water resources

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Chapter 1
INTRODUCTION

1.1 What is landscape approach?

The terms *landscape, landscape approaches* and *integrated landscape management* (ILM) are among the various landscape-focused terminologies that underpin discourse among contemporary researchers and advocates working on the interlinkages between conservation, agriculture and other land uses (Sunderland 2014). According to the Oxford English Dictionary, the term *landscape* has been defined as all the visible features of a piece of land and often considered for their visual and aesthetic appeal (2017). However, at the beginning of the 21st century, the European Landscape Convention (ELC) detailed out a comprehensive framework for the term landscape and defined the same as 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors'. Furthermore, landscape management are actions taken to ensure the regular upkeep of a landscape for sustainable development with the aim to guide and harmonize changes which are brought about by social, economic and environmental processes (Council of Europe 2000). The landscape approach gained popularity in research, planning and management of natural resources due to the comprehensive framework outlined at the convention.

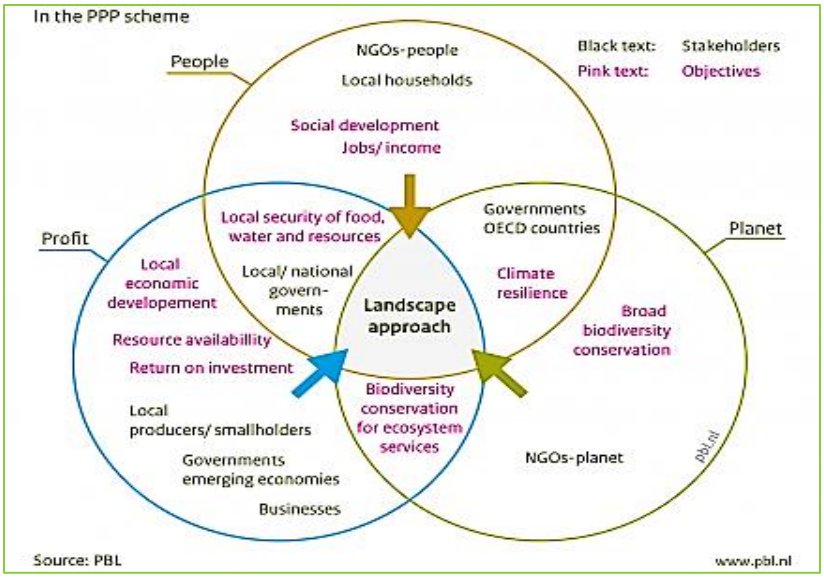


Figure 1: Overview of the stakeholders and objectives pursued in landscape approach

The *landscape approach* aims to integrate policy and practice for multiple land uses, within a given area, to ensure equitable and sustainable use of land while strengthening measures to mitigate and adapt to climate change (Scherr et al. 2012; Milder et al. 2012; Sayer et al. 2013; Harvey et al. 2014).

It also aims at balancing competing demands on land through the implementation of adaptive and integrated management systems. These include not only the physical characteristic features of the landscape itself, but all of the internal and external socio-economic and socio-political drivers that affect land use, particularly related to conservation, forestry and agriculture (Sayer et al. 2013). In short, landscape approach seeks to address the increasingly complex and widespread environmental, social and political challenges that transcend traditional management boundaries (Reed et al. 2014).

1.2 The importance of the landscape approach

Globally, environmental degradation was perceived as a natural consequence of economic progress. With time, this perception has slowly been replaced by the realization that the long term economic cost of environmental degradation far outweighs the immediate commercial benefits. This has resulted in the urgent need to improve our approach towards development in a manner that is aligned to ecological conservation and sustainability. The need to adopt a landscape approach has also been recognized by private investors and companies to mitigate environmental, health, and social risks that threaten their profitability and the long-term viability of their business models (Melissa et al. 2015).

A sustainably managed landscape can meet a complete range of local needs consisting of:

- **<u>Water availability</u> for households, farms, businesses and agriculture**
- **<u>Biodiversity</u> for crop pollination, production of nutritious**
- **<u>Profitable crops</u> for families, markets and industry and improvement in human health while also contributing to global SDG (Melissa et al. 2015).**

The past decade has seen a growing global acceptance of the integrated landscape management approach, in situations where challenges and opportunities call for a simultaneous increase in food production, improvement in livelihoods, and protection of biodiversity and ecosystem services (Estrada-Carmona et al. 2014). This white paper follows the ten principles of the landscape approach emphasizing adaptive management, stakeholder involvement, and multiple objectives (Sayer et al., 2013) for improved ***land – water – community security*** (figure 2).

Figure 2 : Ten principles of the landscape approach for improved land – water – community security
(Source: Sayer et al., 2013)

Due to these multiple benefits and the complexities; in addition to the interrelated nature of the local needs and current global challenges; ILM can contribute significantly to implementing the Sustainable Development Goals (SDG) (Mbow et al. 2015) (figure 3). The ten principles as presented in Figure 2 characterizes ILM, an approach that shall facilitate in the achievement of multiple SDGs (Scherr et al. 2013; Sayer et al. 2013).

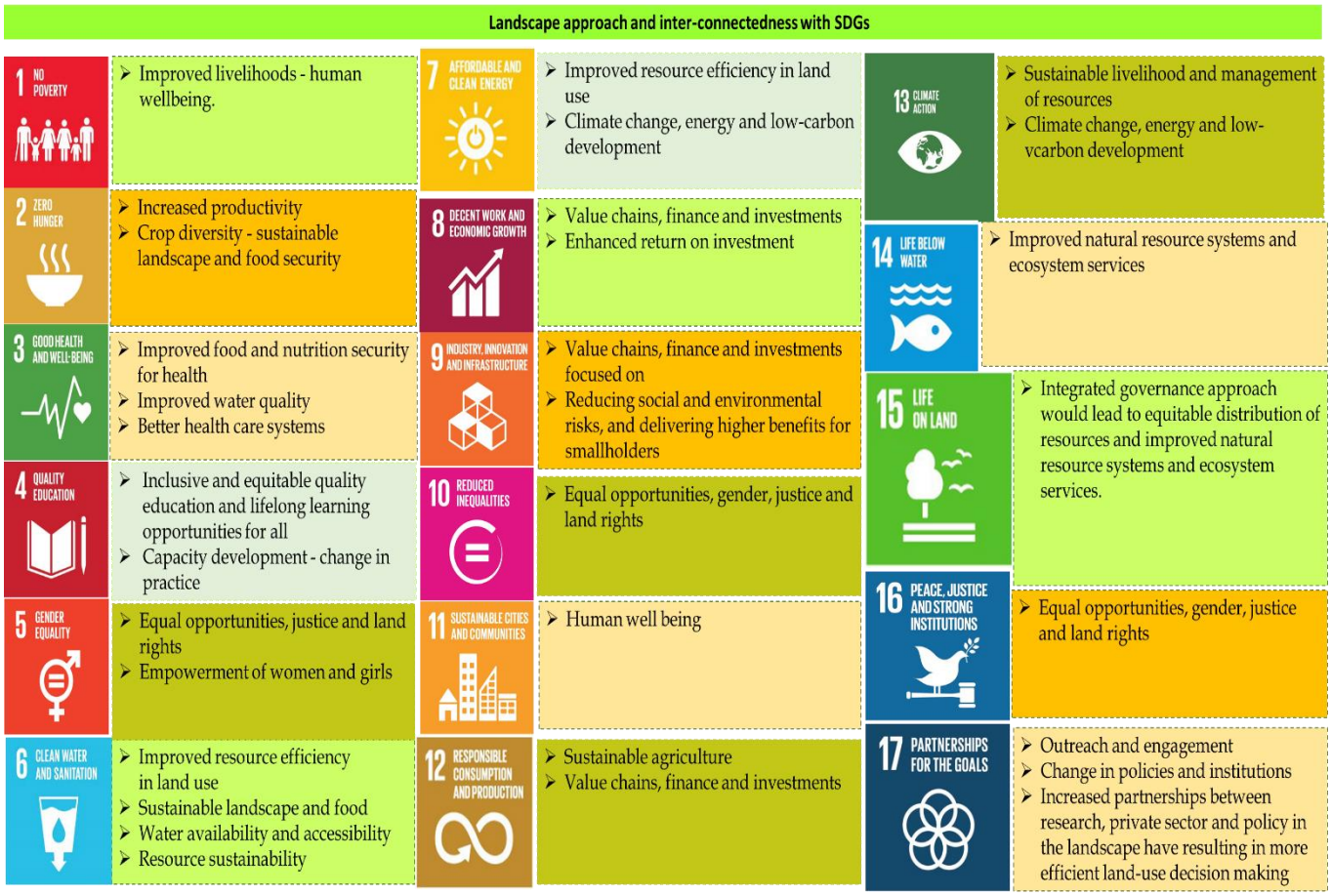


Figure 3: Landscape approach and inter-connectedness with SDGs

1.3 The need for landscape approach in the mid Gangetic belt of Uttar Pradesh

The central parts of UP present a fit case for adopting the landscape approach to river basin management that will lead to restoration, rejuvenation of the entire eco-bio-system on a robust *'People, Planet, Profit (PPP)' model.*

The landscape approach, aiming to allocate and manage land to achieve balanced socioeconomic - ecological outcome, calls for recognition of multiple stakeholders, conflicting goals, and land use practices that have implications for the physical environment, habitat and natural resources. The mid-ganga basin in UP is witness to this pressure and consequent impact on the riverine resource system. The river in the middle parts largely entering the plains and supporting intense agricultural activities through canal systems impacts the flow downstream. Along the stretch several towns, industries and agricultural activities contribute to point and non-point sources of pollution. A general degradation in the river system is caused by riverside cash crop farming (example: sugarcane), indiscriminate sand/gravel mining, riverbed farming, unscientific fishing, open defecation etc. (CPCB, 2013). Rapid urbanization along the river banks is imposing additional pressure on the already degrading resources. In general, the nature of use of water resource has affected both the flow and the quality of water in the mid Ganga basin. The short and long-term consequences of this impact shall be felt both by the physical environment and the society and is of great significance for this densely populated state where almost 40 % of the population is below the poverty line.

1.4 Objectives of the study

The study helps to embed the landscape approach into river basin management. It suggests that planning for a robust socio-ecological system requires that resource decisions (and consequent tradeoffs) be based on sound principles of equity, efficiency and participation while balancing these with ecological principles such as resilience.

The study aims to provide and in-depth analysis of the land and water use and the process of allocation of these resources. Secondly, the paper aims to develop a framework of necessary development interventions using the landscape approach and observing the river (ecological) systems in consonance with the socio-cultural systems with special focus on resource allocation decisions involving tradeoffs. Planning for a robust socio-ecological system requires that resource

decisions (and consequent tradeoffs) be based on sound principles of equity, efficiency and participation while balancing these with ecological principles such as resilience.

For this work, landscape is given a territorial dimension and encompasses a complex milieu of ecological (including soil, water, pastureland etc.) and socio-cultural sub-systems (such as human settlement, communication network and institutional arrangements).

1.5 Site description

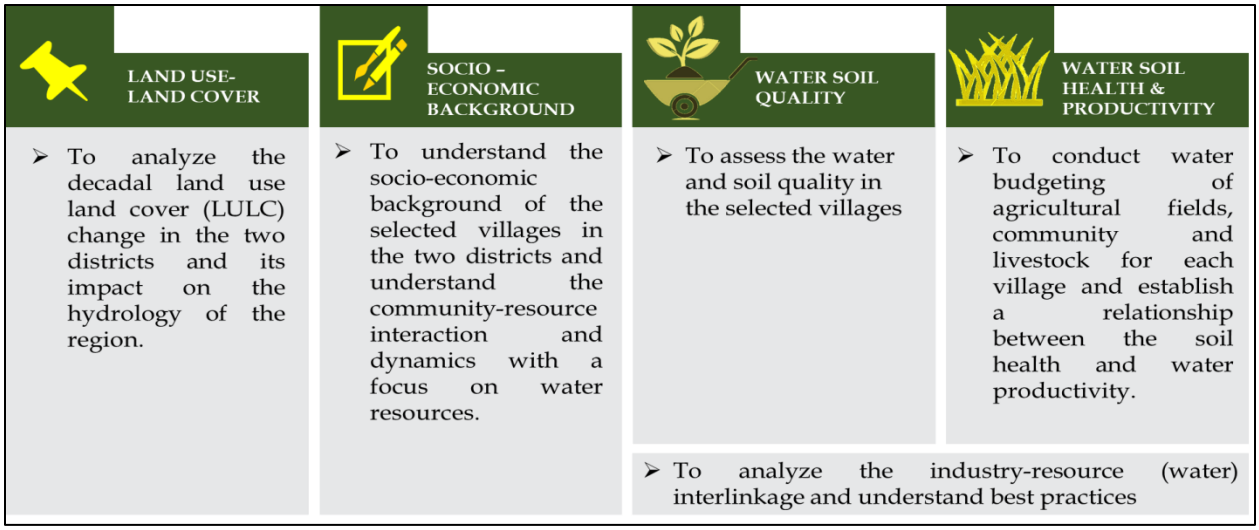


Figure 4: Key objectives of the study

Mid-Ganga basin is one of the most populous and highly agricultural intense region of the Ganga basin. Generally, the agricultural activities are carried out through various canal networks that in turn hampers the flow of the water downstream causing water availability problems. The middle reach also supports many megacities on its bank which pollutes the river by disposing untreated wastewater both from industries and domestic in the river. The middle Ganga stretches between Kanpur and Varanasi is susceptible to the maximum pollution having a total discharge of around 3000 MLD of wastewater having biological oxygen demand (BOD) load of 738,152 Kg/day (Narain, 2014). The nature of water resource utilization in the mid-ganga basin has imposed severe pressure on the water resource both in terms of quality and quantity.

The study was conducted in the two districts of mid-Gangetic plain i.e., Hardoi, Lakhimpur Kheri and Kanpur.

A. Kanpur

Kanpur Nagar is one of the highly urbanized and industrialized area of the Ganga river basin. It is situated between 25° 26'N and 26° 58' N latitude and 79° 31'E and 80° 34' E longitude and having an elevation of 126 m above the sea level. The district is one of the megacities in UP. It is located at the center of two major rivers of the northern India i.e. Ganges in the North and Yamuna at the South. The average annual rainfall of the district is about 821.9 mm out of which 90% takes place during June to September months. Being the part of the Ganga basin, major soil type found in the area is loamy (Srivastava, 2009). It has a population of around 4.5 million with the population density of 1452 persons/Km^2 (Census, 2011). The district is actively involved in the agricultural activity constituting around 62% area as net cultivable area and having rice and wheat as main Kharif and Rabi crops (C-DAP, 2008). Kanpur is also famous for its leather industries having approximately 400 tanneries. Besides tanneries cotton and woolen industries are also present in Kanpur city. The wastewater of Kanpur city is drained by total of 26 drains of which 21 drains flow into the river Ganga and five drains flow into the river Pandu) (CPCB, 2016). Wheat and rice constitutes the major crops during the Rabi and Kharif season respectively. Other crops which are also grown in this area are jowar, potato, pulses, oilseeds, sugarcane and vegetables.

B. Hardoi and Lakhimpur Kheri

The study area Hardoi is situated between 26º 53' and 27º 46' North latitude and 79º 41' and 80º 46' East longitude having mean elevation of 136 m above sea level. The average annual rainfall of the district is about 941 mm. The district has a population of around 4 million with population density of around 682 persons/Km^2. The district has many sugarcane mills in the northern part of Hardoi and forms the main sugarcane growing belt of the region. The main rivers of the district are Ganga and Ramganga other rivers in the district are Sai, Garra and Gomti. Agriculture forms the major occupation in the district constituting around 70% of the geographical area of the district which is fed by the Sharadha canal network. Wheat and rice constitutes the major crops during the Rabi and Kharif season respectively whereas sugarcane forms the major cash crop of the district. Other crops which are also grown in this area are maize, pulses and oilseeds. A total of eight villages were studied in the districts of Hardoi, Lakhimpur Kheri and Kanpur Nagar. A description has been presented in figure 5 and 6.

DISTRICTS HARDOI AND LAKHIMPUR KHERI

KAZIBADI

- This is a small village in Todarpur Panchayat, with approximate population of 1630 (Census of India, 2011) residing in close to 400 households.
- Majority of the population belongs to the OBC category.
- The primary occupation is agriculture and labour. Most of the farmers are in medium and small category.
- Major crops grown are sugarcane and wheat.

BHARKHANI

- This is a block village and Panchayat and has population of 5681 residing in 888 families (Census, 2011; the villagers however estimated the population as approximately 10,000 in 1200 households in 2017).
- This is a multi-caste village inhabited by general, OBC and SC categories. Farmers primarily cultivate wheat while few have also started growing sugarcane.
- Land distribution is skewed and there are many large farmers, especially among the upper caste (general category).
- **Bharkhani has a woman Sarpanch.**

SEMAR GHAT

- This is a Panchayat village located in Mohammadi Tehsil of Lakhimpur Kheri.
- As per Census 2011, the village had a population of 1205 in 251 households (the villagers however stated the population as approximately 2500 in about 200 households as per data collected in April 2017).
- The village population is a mix of general, SC and OBC categories. The village also had a few Sikh families that had settled almost five decades back and have large landholdings.
- The main occupation include agriculture, dairy and labour. Main crops grown in the village include sugarcane and wheat.

DISTRICT KANPUR NAGAR

SHEIKHPURA

- This is in the district of Kanpur Nagar and is surrounded by the banks of river Ganga.
- As per census, village comprises of 109 households with its estimated population of 558 people.
- Agriculture is mainstay of the population. It largely depends on CETP canal water and rainfall for irrigation with very few pump connections. Though the groundwater level is good, but the quality of water is poor.

AIMA GRAM PANCHAYAT

- This is in the district of Kanpur Nagar; the village falls under the Sarsol block.
- As per 2011 Census, village comprises of 276 households with its estimated population of 1509 people.
- Agriculture is the dominant occupation. It largely depends on the groundwater and rainfall for irrigation.
- Segregated social groups mark the territorial boundary of the village. Thus, out of the five villages - **Aima, Karbi, Gadiyampurva,** Bagicha and Karankhera; first three were selected for this study to represent General, SC and OBC categories
- **Aima Gram Panchayat has a woman Sarpanch**

Figure 5: Description of the villages in the study area

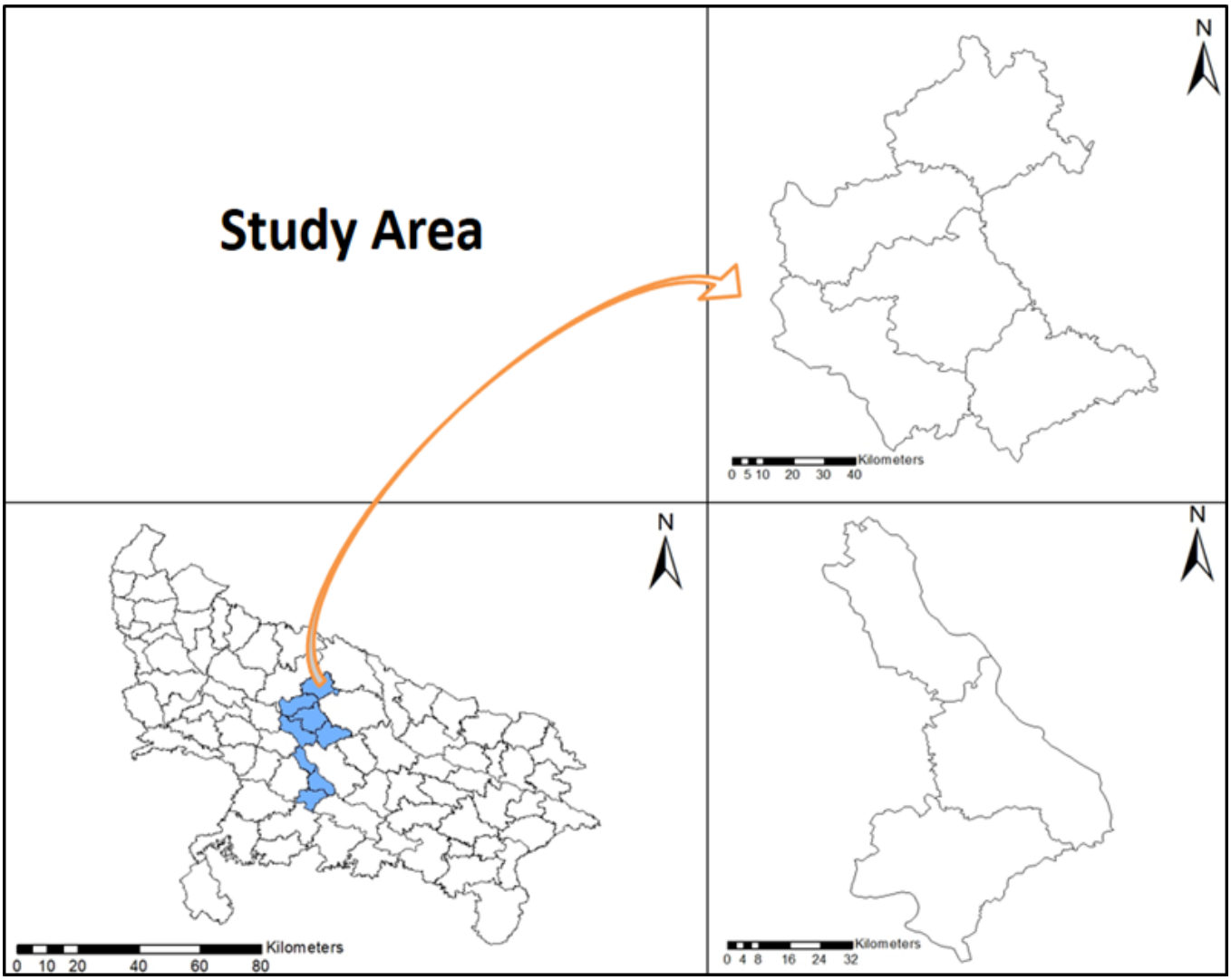


Figure 6: Two study sites in Mid-Ganga river basin (a) Hardoi district and Mohammadi tehsil of Lakhimpur Kheri (b) Kanpur Nagar district

Chapter 2
LAND USE DYNAMICS AND ITS HYDROLOGICAL IMPLICATIONS IN THE REGION

2.1 Introduction

The objective of this chapter is to investigate decadal change in land use practices and its impact on hydrology of the region. Specifically, the study focuses on change in land use in an industrial belt (Kanpur) and sugarcane growing regions (Hardoi and Lakhimpur). Most of the industries in the region are in Kanpur Nagar and agricultural activities are concentrated in Hardoi and Lakhimpur districts. In Kanpur Nagar, the industries are situated around the densely populated areas of Kanpur city. The city alone has around 400 leather-tanning industries and several other small-scale industries such as cotton, woolen and other agro-based industries. These industries use groundwater and dispose of wastewater in the river Ganga.

The two districts, Hardoi and Lakhimpur have more than 70% of their area under cultivation (DCP, 2008). The dominant crops in these districts are wheat, rice, sugarcane, maize, pulses and oilseeds. The northern part of Hardoi forms the major sugarcane growing belt and has many big sugar mills in the area as this area is attached to the upper Lakhimpur district which is the sugarcane belt of UP. The study is carried out in Kanpur Nagar and Hardoi districts and Mohammadi tehsil of Lakhimpur.

OBJECTIVES OF THE STUDY

1. **Investigating the land use change in 10-15 years in the region;**
2. **Understanding the implication of these changes on different physical components such as evapotranspiration and groundwater recharge in the area.**

2.2 Data collection and methodology

A. Dataset

The study uses both primary and secondary data collected from several sources.

- **Spatial data:** The satellite data and other data sets concerning topography, soil and meteorological parameters were used for this analysis.

- **First site:** The Hardoi and Mohammadi tehsil of Lakhimpur Kheri has been covered in one imagery (path/row: 144/041) of Landsat 7 and Landsat 8 dataset.
- **Second site**: The Kanpur Nagar district is covered in 144/042 (path/row) of Landsat 7 and Landsat 8 dataset.

The 30-meter spatial resolution Landsat 7 (ETM+) and Landsat 8 dataset for the two study sites were used for the analysis. The data sets were downloaded were downloaded from Earth explorer website of the United Stated Geological Survey (USGS) and analyzed for 2002 and 2016 for Hardoi site and 2006 and 2016 for Kanpur Nagar for understanding the change in land use. Since, both the study sites have several crops grown around the year; satellite data for the three seasons of Rabi, Kharif and Zaid were acquired for the analysis for the two years for both the sites.

- **Digital elevation model (DEM)** of the area was extracted from ASTER GDEM (Global Digital Elevation Model). The spatial resolution for the DEM is 1 arc second (~ 30m).
- **Soil map** for the study area was also downloaded from the Food and Agriculture Organization's harmonized world soil database (version 1.2) and was clipped for the study area.
- **Meteorological parameters** such as temperature (maximum, minimum and average), solar radiation, precipitation, relative humidity, dew point temperature and wind speed) available at 1° x 1° resolution were downloaded from NASA POWER project (NASA-POWER, 2015).

B. Methodology

The methodology followed to investigate and evaluate the land use land change in the region was

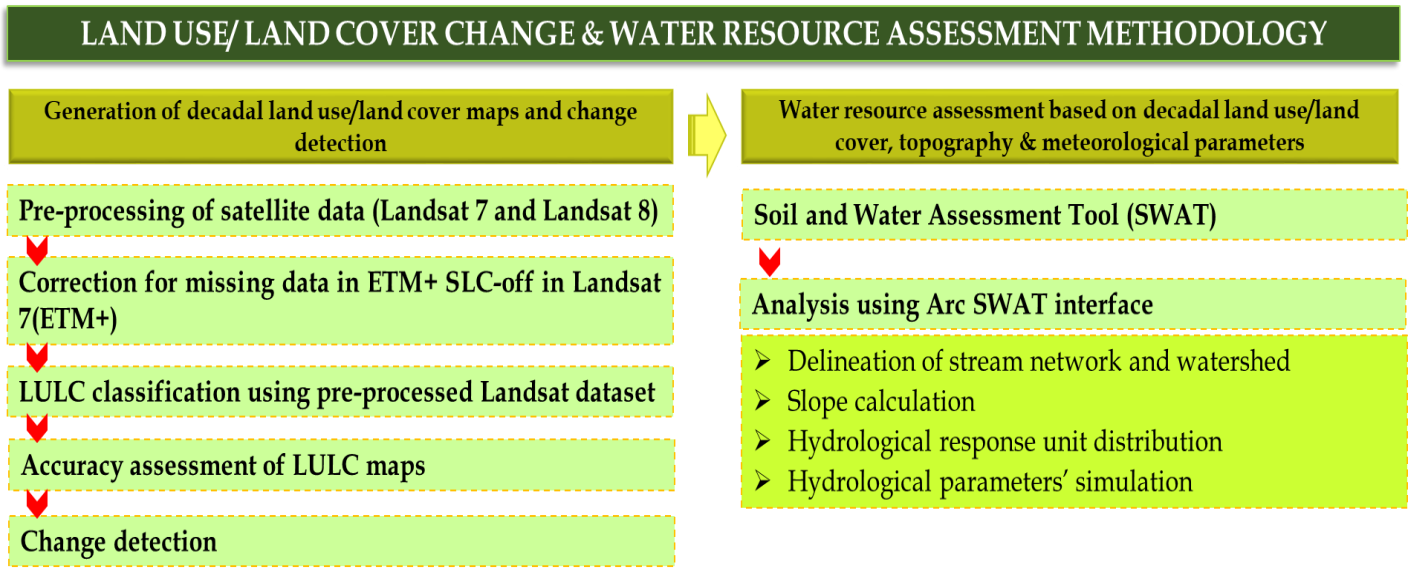


Figure 7: Land use/ land cover change & water resource assessment methodology

two pronged (figure 7). The first was to investigate decadal land use/land cover change and the second to identify the implications of these changes on existing water resources.

1. Generation of decadal land use/land cover maps and change detection

The land use/land cover change for the two study sites were analyzed using reflectance bands of Landsat data for the two years. The generation of land use/land cover map include following steps:

- **Pre-processing of satellite data (Landsat 7 and Landsat 8) –** The bands in the dataset in visual, near infrared and shortwave infrared region of electromagnetic spectrum were used for the analysis. The pre-processing step involves correction of radiometric error. These kinds of error could be internal due to issue with sensor itself or external such as atmospheric interference, difference in the sun angle during the acquisition of satellite imagery. All the Landsat imageries were radiometrically corrected and converted into top of the atmosphere reflectance (TOA). The formula for converting digital number of individual bands to TOA is given in equation 1(U.S. Department of Interior, 2013).

$$\rho_\lambda = M_P * Q_{cal} + A_P \qquad (1)$$

where,
ρ_λ= TOA reflectance
M_P = Band specific multiplicative rescaling factor
A_P = Band specific Additive rescaling factor
$Qcal$ = input digital number

The conversion of digital number of Landsat 7 data involves two steps (Mss *et al.*, 2009)
Conversion of digital number to radiance (equation 2) and conversion of radiance to the top of the atmosphere (TOA) reflectance (equation 3)

$$L_\lambda = \frac{LMAX_\lambda - LMIN_\lambda}{Qcalmax - Qcalmin}(Qcal - Qcalmin) + LMIN_\lambda \qquad (2)$$

Where,
L_λ = Spectral radiance and sensor aperture
$LMIN_\lambda$ = Spectral at-sensor radiance scaled to Qcalmin
$LMAX_\lambda$ = Spectral at-sensor radiance scaled to Qcalmax
Qcal = Digital number value of input image
Qcalmin = Minimum quantized calibrated pixel value corresponding to $LMIN_\lambda$
Qcalmax = Maximum quantized calibrated pixel value corresponding to $LMAX_\lambda$

$$\rho_\lambda = \left(\frac{\pi . L_\lambda . d^2}{ESUN_\lambda . \cos\theta_s}\right) \qquad (3)$$

Where,
ρ_λ= TOA reflectance
π = constant (3.14)
d = Earth - sun distance
$ESUN_\lambda$ = Mean exoatmospheric solar irradiance
Θs = Solar zenith angle (90- sun elevation angle)

- **<u>Correction for missing data in ETM+ SLC-off in Landsat 7(ETM+)</u> –** The data acquired by Landsat ETM+ after 31st May, 2003 suffered from sensor failure leading to scan line issues called SLC-off (scan line corrector off). In our study area, the effect of SLC-off was more pronounced towards the edges of the image whereas center area was free from this error. **The missing data were filled by using interpolation approach in the image processing software** (Erdas 2014). Since, majority of the study area was at the center of the scene there was very less effect of SLC-off error on the image.
- **<u>Land use/land cover classification using pre-processed Landsat dataset</u> –** The land use/land cover map for the three seasons (March: Rabi, May: Kharif and October: Zaid) was generated taking into consideration the two agricultural and industrial belts for a period of two years using a supervised classification, i.e., the maximum likelihood approach. In the **maximum likelihood approach**, the pixels are assigned to a class on the basis of the likelihood of a pixel belonging to a particular class (Erdas, 1997). The likelihood is defined in terms of posterior probability of the pixel given equal probability of all the classes to occur in the landscape.

  The training data pertaining to different land use/land cover collected from the field, *Google Earth Engine* were used for training the model. These training sites were collected using **random sampling approach for each class**. To ensure each of the sites truly represent the landscape, care was taken to take multiple training points from different part of the landscape for all the classes. These training sites were then subjected to further test to evaluate spectral separability between the classes. The **transformed divergence method** was used to test the separability between different classes and further modification of training data was carried out. The classes were selected based on the level one classification scheme as defined by (Anderson *et al.*, 1976). **The main classes which were considered for the study area were urban settlement, agricultural land/pasture land, barren/ fallow land, water bodies, and riverbeds. The classified outputs for the three seasons of a year were combined to generate land use/land cover map for that specific decade.**
- **<u>Accuracy assessment of land use/ land change maps</u> –** It is important to know the accuracy of a land use/land cover map before using it for further analysis. The **accuracy assessment of land use/land cover maps for the three seasons were assessed using Kappa index**. This index estimates the accuracy by considering all the pixels in the reference data that were correctly classified and penalizes for chance agreement. The index is calculated using equation four (Dewan and Yamaguchi, 2009). The reference data collected from ground or by using

Google earth. Using random sampling approach, a total of 100 points were collected from all the classes.

$$\kappa = \text{(Observed accuracy - chance agreement)} / \text{(1 - chance agreement)} \quad (4)$$

Observed accuracy means all those locations where both reference and mapped pixels have class. The chance agreement is the error introduced by omitting a pixel from a class or committing an error by classifying a pixel to a class. **At all the reference locations, the class information was extracted from the land use/land cover map generated for 2006 and 2016 for Kanpur Nagar, in addition to the kappa index being calculated. Similarly, classes were identified on the grounds for the year 2002 and 2016 in the agriculture belt of Hardoi and Mohammadi tehsil of Lakhimpur Kheri and kappa index was also calculated**.

- **Change Detection:** The decadal maps for the study site were overlaid over each other to identify the locations where there has been change in land use practices over the years. **The analysis was carried out in TerrSet software and outputs are graph describing all sets of transition of classes along with map of change.**

2. Water resource assessment based on decadal land use/land cover maps

The assessment of existing water resources was carried out using the Soil and Water Assessment Tool (SWAT). SWAT is used for simulation of run-off and evapotranspiration from a watershed.

$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw}) \quad (5)$$

Where,

SW_t = Final soil water content (mm H_2O)
R_{day} = Amount of precipitation on day *i* (mm)
Q_{surf} = Amount of surface runoff on day *i* (mm)
E_a = Amount of Evapotranspiration on day *i (mm)*
w_{seep} = Amount of percolation and bypass flow in soil on day *i* (mm)
Q_{gw} = Amount of return flow on day *i* (mm)

The analysis was carried out using ArcSWAT interface as it combines SWAT in the GIS platform. The SWAT modelling involves following steps:

- **Delineation of stream network and watershed**: The stream network and watershed was delineated using DEM of the area as seen in Figure 11 in automatic watershed delineation module of the ArcSWAT interface.

- **Slope calculation**: The slope was calculated for each sub-basin which was used for defining Hydrological Response Unit (HRU).
- **HRU distribution**: The HRU's are the groups of areas having a unique combination land use, soil and slope definitions. The input for defining HRU in the delineated watershed are land use, soils and slope of the area
- **Hydrological parameters' simulation**: These HRU's along with meteorological parameters are used for simulating hydrological parameters of the watershed. Finally, **simulation time period is selected along with warm-up period for setting up and running of the model**. **A warm-up time of 3 years was taken in both the cases. The warm-up year is set so that the hydrology of the area can get stablized**. For the smaller period of simulation it becomes essential to give a warm-up period to the model (Neitsch *et al.*, 2002). A minimum of 3-5 year of warm-up period is always recommended for a model to properly run. The run-off of the watershed was calculated using SCS (Soil Conservation Services) curve number procedure and the Evapotranspiration of the area was calculated using Penman-Monteith method (Neitsch *et al.*, 2011).

The SWAT model was run for both the study sites. In the sugarcane belt, LULC maps was created for 2002 and 2016 to understand the impact of change in land use/land cover on run-off volume in the watershed. However, In the industrial belt, the LULC maps of 2006 and 2016 were used for the modeling.

This approach for determining impact of LULC on hydrology can be utilized where there is non- availability of discharge data (Wagner et al. 2013). The discharge data of the river Ganga is difficult to obtain as the same is categorised as classified data because of its status as a trans-boundary river. Thus, this was the described approach undertaken for the present study.

2.3 Findings

The analysis on agriculture in Hardoi district and Mohammadi tehsil of Lakhimpur Kheri and industrial belts in Kanpur Nagar situated on the mid-Ganga river basin suggest different land use practices and its impact on water resources.

A. Land use/land cover change

The land use/land cover change in last 10-15 years industrial belt and agricultural belt are different when analyzed using Landsat 30-meter dataset.

- **Urban area focused industrial expansion:** Most of the industrial expansion has occurred near Kanpur city leading to increase in urban area (3160 ha) around Kanpur city in the last 10

years (Table 1). These changes have occurred at the cost of fallow/barren lands and agriculture/pasture lands in and around the city. **This could have serious implication on water resource in the area as the lands with good infiltration capacity have been converted to concrete structures putting pressure on the groundwater resources by decreasing the groundwater recharge capability of the area** (Figure 8a & 8b).

The district has large area under agricultural activities with most of the cropping carried out in Rabi and Kharif season (Figure 8a & 8b, Table 1). Almost, 87% of total district area in 2006 was used for agricultural activities in one season or other. In 2016, approx. 86% of total area was used for growing different crops. The total area of agricultural land used for the whole year for cropping was found to be 8% and 18% in 2006 and 2016 respectively (Table 1). This increase is mostly associated with the increase in zaid cropping which can be also seen in the increase in the area where only zaid crops are grown. This could be attributed to increase in the number of tube wells in the area leading to availability of water for irrigation. The summer crops in the area mainly constitute vegetables, corn and flowers. However, there is decline between 2006 and 2016 in cropping especially in Rabi and Kharif seasons (Table 1).

Table 1: LULC statistics for Kanpur Nagar

	2006		2016	
LULC CLASSES	**Area (Ha.)**	**Area (%)**	**Area (Ha.)**	**Area (%)**
Urban settlement	7673.0	2.62	10833.1	3.7
Water bodies	1961.7	0.67	2185.8	0.75
Riverbeds	864.1	0.3	613.7	0.21
Fallow/Barren lands	21017.0	7.19	20342.4	6.95
Agriculture (Rabi, Kharif and Zaid)	21834.5	7.47	46501.9	15.9
Agriculture (Rabi & Kharif)	149175.7	51.02	115988.9	39.65
Agriculture (Kharif &Zaid)	1566.7	0.54	10991.9	3.76
Agriculture (Rabi &Zaid)	4300.3	1.47	10536.1	3.6
Agriculture (Rabi)	47384.5	16.21	31786.4	10.87
Agriculture (Kharif)	27863.7	9.53	15965.8	5.46
Agriculture (Zaid)	4043.3	1.38	22475.0	7.68
Forest	4695.3	1.61	4324.5	1.48

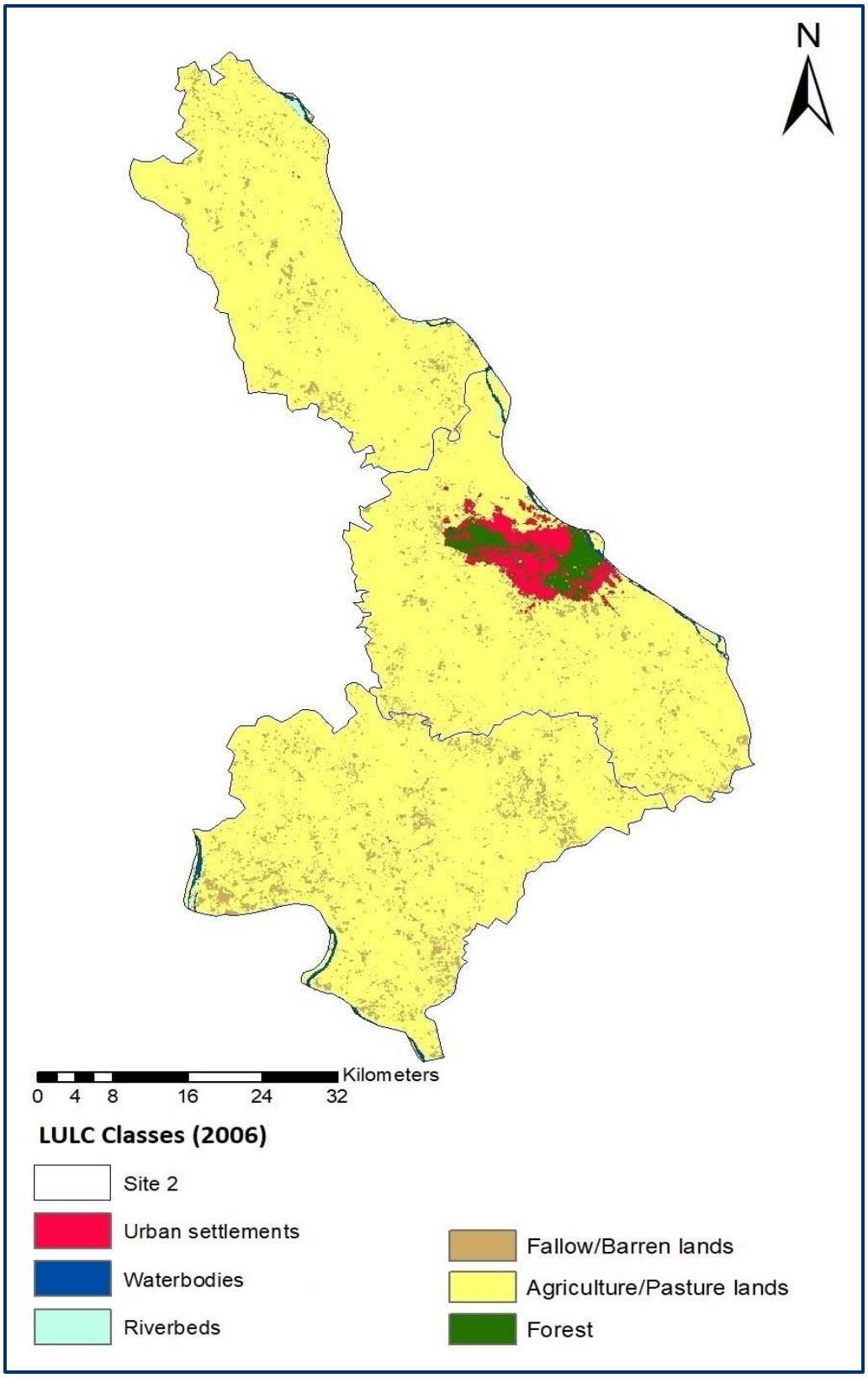


Figure 8a: LULC in Kanpur in 2006

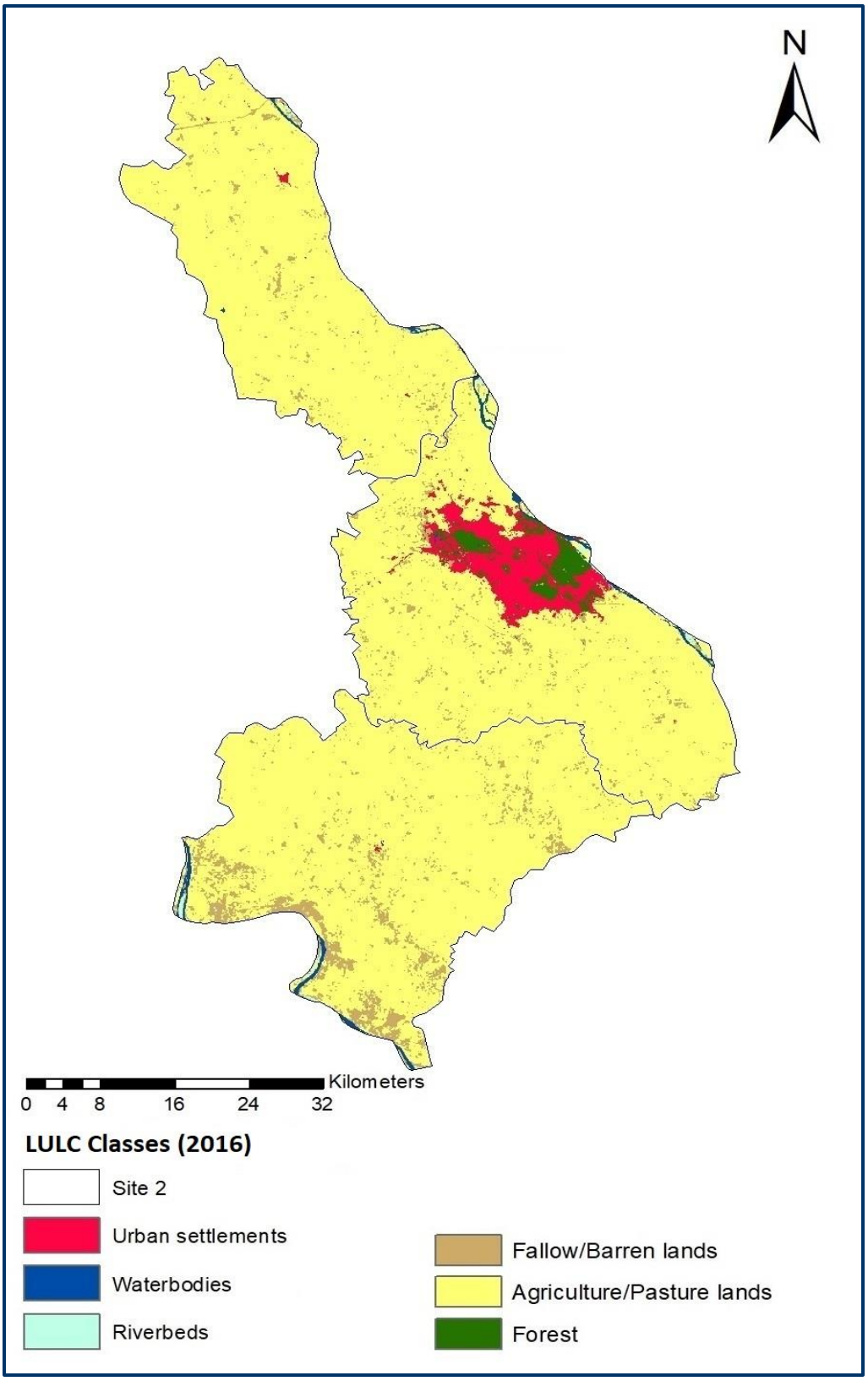


Figure 8b: LULC in Kanpur in 2016

- **<u>Spatial patterns of transitions:</u>** Figure 9 showcases the spatial patterns of all transitions. A key finding of the study was the increase in urban are mainly at the cost of agricultural or pasture lands, fallow or barren lands and forest area.

    - **This suggests that vegetation in and around the city area has been used to accommodate the growing population**.
    - Furthermore, there has also been a net decrease in the fallow and barren lands indicating that these lands have been taken up for urban expansion. The transition of fallow or barren land to agriculture or pastural use could be attributed to tendency of farmers in this area to keep land as fallow for few years before sowing some crops (DPC, 2008).
    - The changes in the **water bodies and riverbeds are due to the meandering of the river where river changes its course on its flood plain** (Nigam et al., 2016).

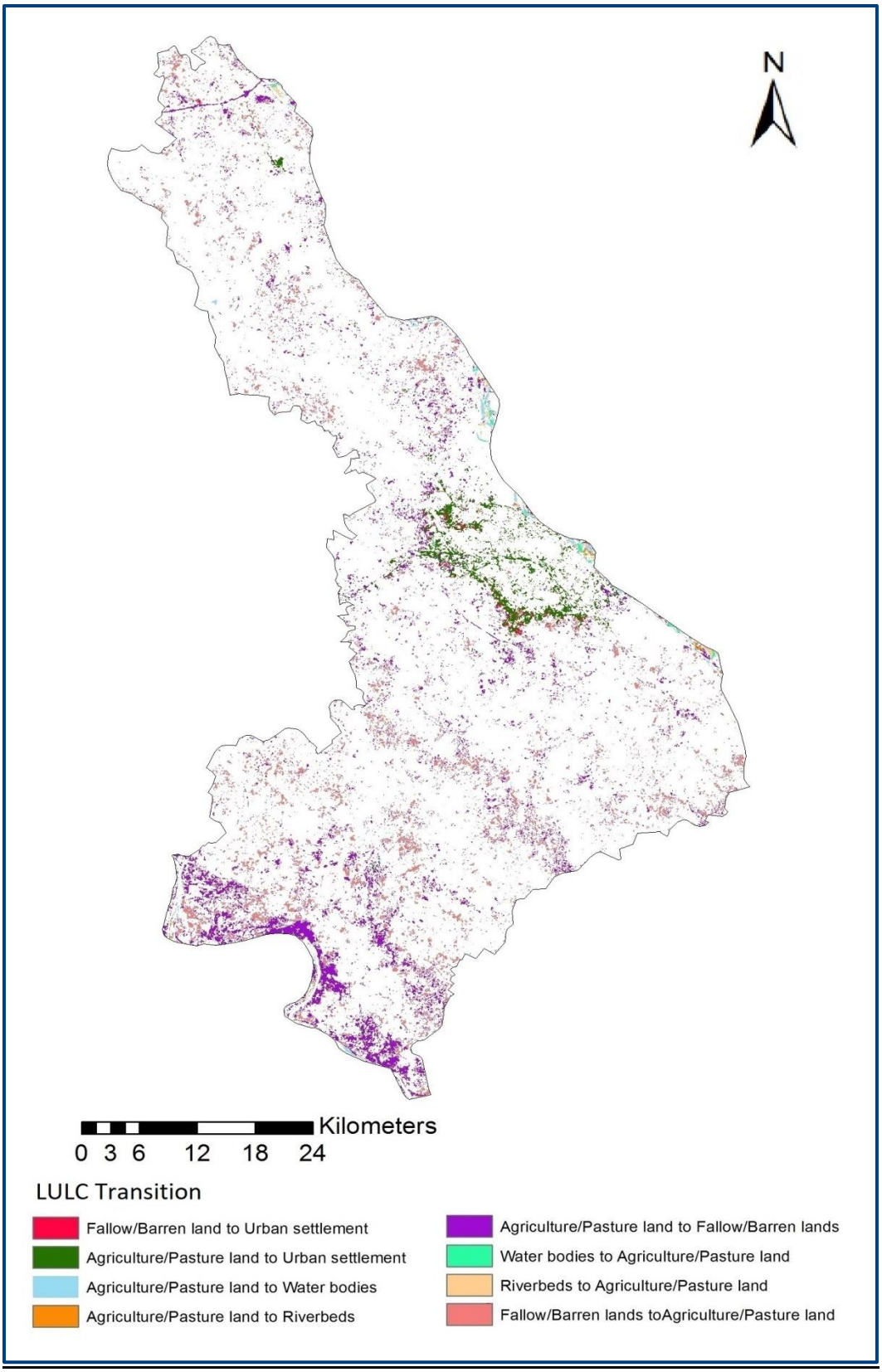


Figure 9: Transition of land use/land cover from 2006 to 2016 in Kanpur Nagar

Agriculture sugarcane belt in Hardoi district and Mohammadi tehsil of Lakhimpur Kheri: Most of land in this belt is under agriculture as showcased in Figure 10.a & 10.b and Table 2. Total area under cultivation which was almost 95% of the total area in 2002 is now 85%in 2016. In general, this transition has occurred on the land where mostly Rabi and Kharif crops were grown in 2002. Almost 63% of the area used for Rabi and Kharif crops in 2006 has reduced to 21% in the 2016 even though there has been slight increase in total area used for Zaid crops. Additionally, there has been an increase in the fallow and barren land between 2006 and 2016 and this increase could be attributed to a decrease in availability of the water in the area. Furthermore, it is interesting to note that most of the increase has been on the western side of Hardoi (Figure 10a & 10b) and this could be due to the lack of proper canal network and groundwater availability in that area.

Table 2: LULC statistics of Hardoi

	2002		2016	
LULC CLASSES	**Area (Ha.)**	**Area (%)**	**Area (Ha.)**	**Area (%)**
Urban settlement	995.31	0.13	1363.95	0.18
Water bodies	10341.63	1.35	4972.41	0.65
Riverbeds	826.38	0.11	1550.52	0.2
Fallow/Barren lands	18105.57	2.36	101758.41	13.28
Agriculture (Rabi, Kharif and Zaid)	83105.37	10.85	76383	9.97
Agriculture (Rabi & Kharif)	493057.71	64.36	167589.45	21.88
Agriculture (Kharif &Zaid)	8072.55	1.05	94794.39	12.37
Agriculture (Rabi &Zaid)	142.29	0.02	16875.18	2.2
Agriculture (Rabi)	79771.68	10.41	177073.83	23.11
Agriculture (Kharif)	67533.3	8.82	76586.58	10
Agriculture (Zaid)	108.72	0.01	43314.84	5.65
Forest	4348.53	0.57	3826.53	0.5

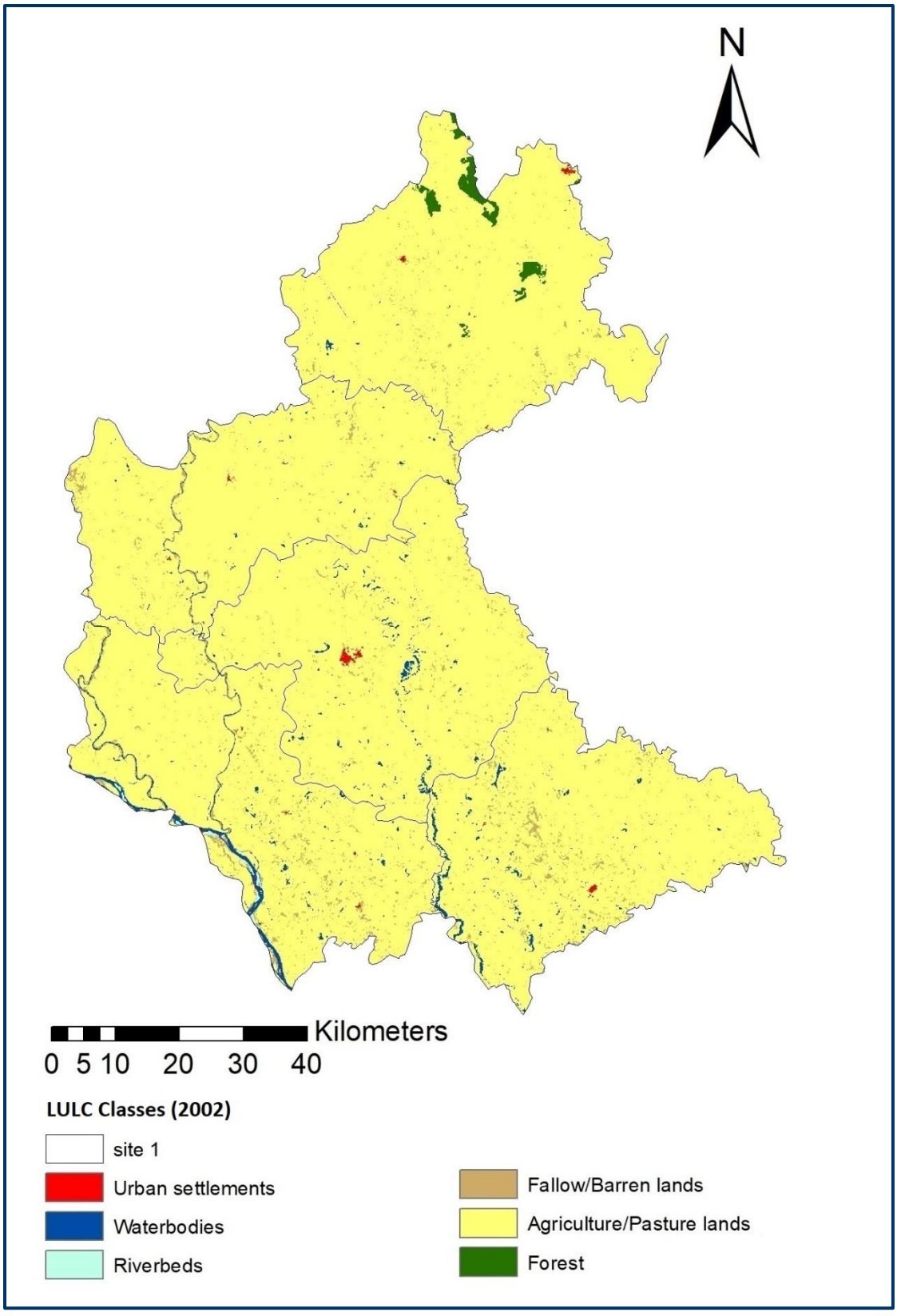


Figure 10a: LULC in Hardoi in 2002

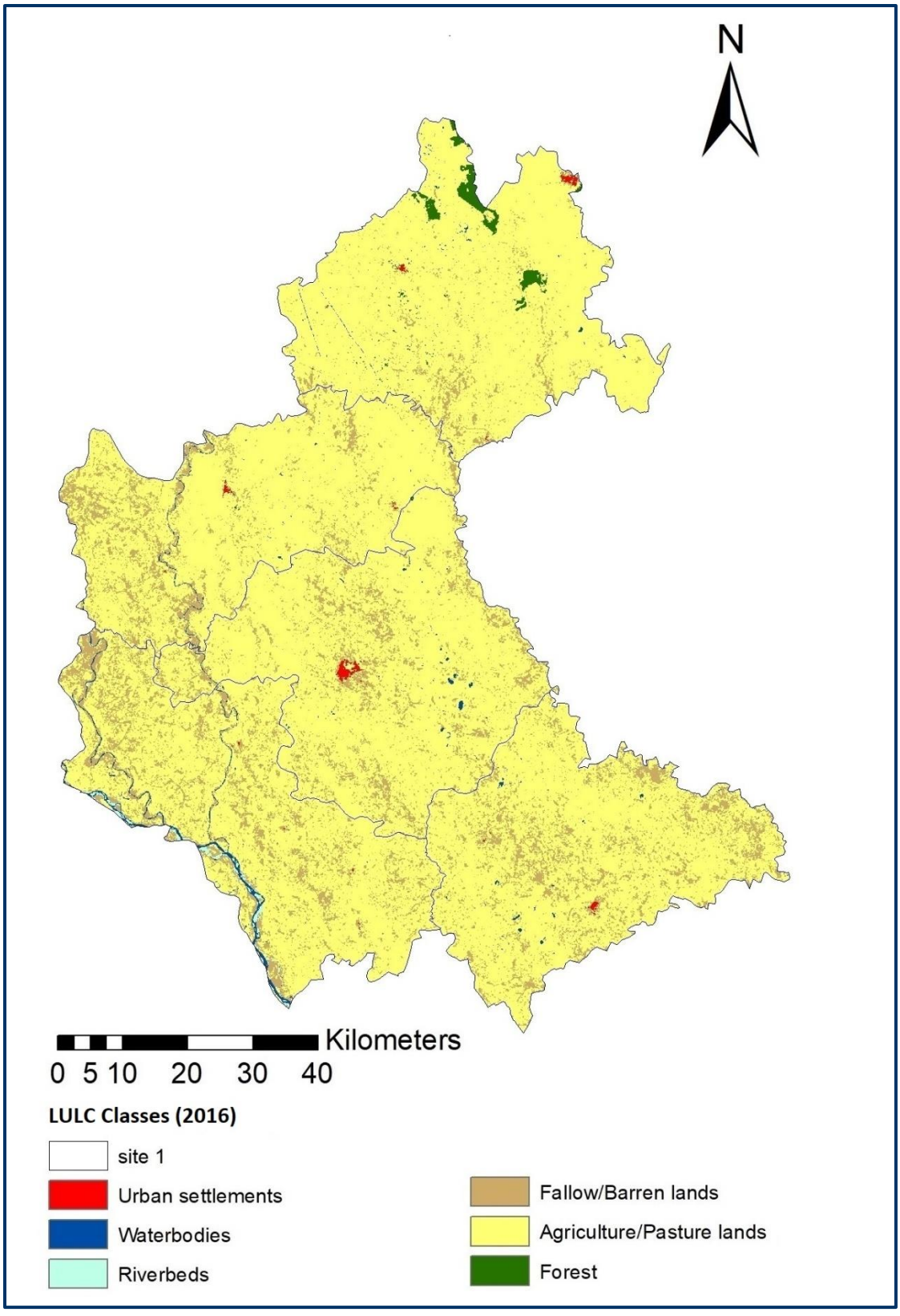


Figure 10b: LULC in Hardoi in 2016

- **<u>Spatial pattern of transition:</u>** The decadal change in the agriculture belt can be seen in western region; northern region of the study area remains mostly stable. As mentioned before these changes are the conversions from agriculture land to fallow or barren land as depicted in Figure 11. There is slight increase in urban area on the land which was used for agricultural activities before.

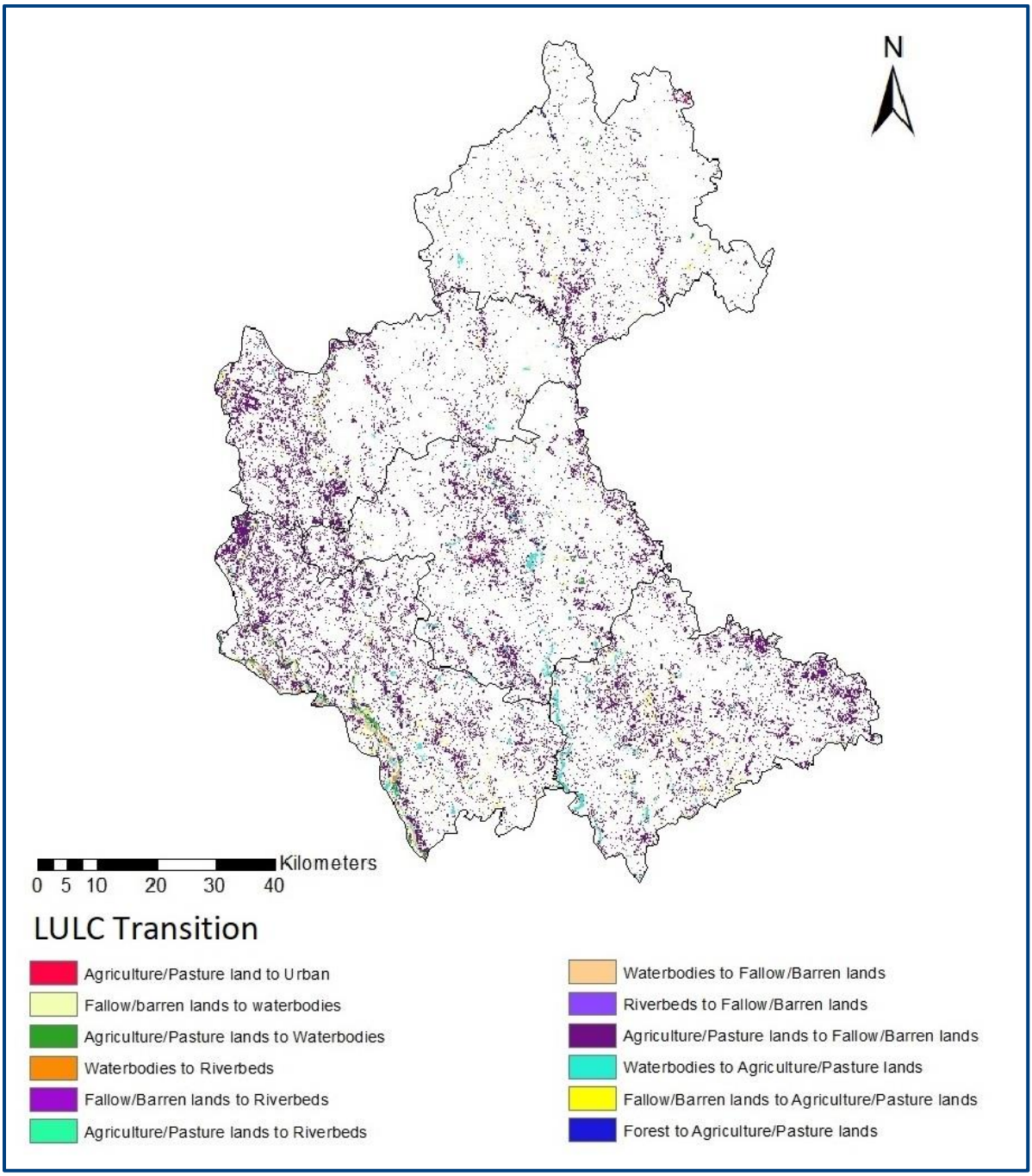


Figure 11: LULC change map of Hardoi

B. *Modeling of water resources in the study area*

To evaluate the water resources in the study area the SWAT model was employed to study the basic water balance in the industry and agriculture belt. The basin and sub-basin were delineated from the watershed delineation function of the SWAT model. The stream networks in the watershed were also delineated from the watershed delineation tab of the SWAT model.

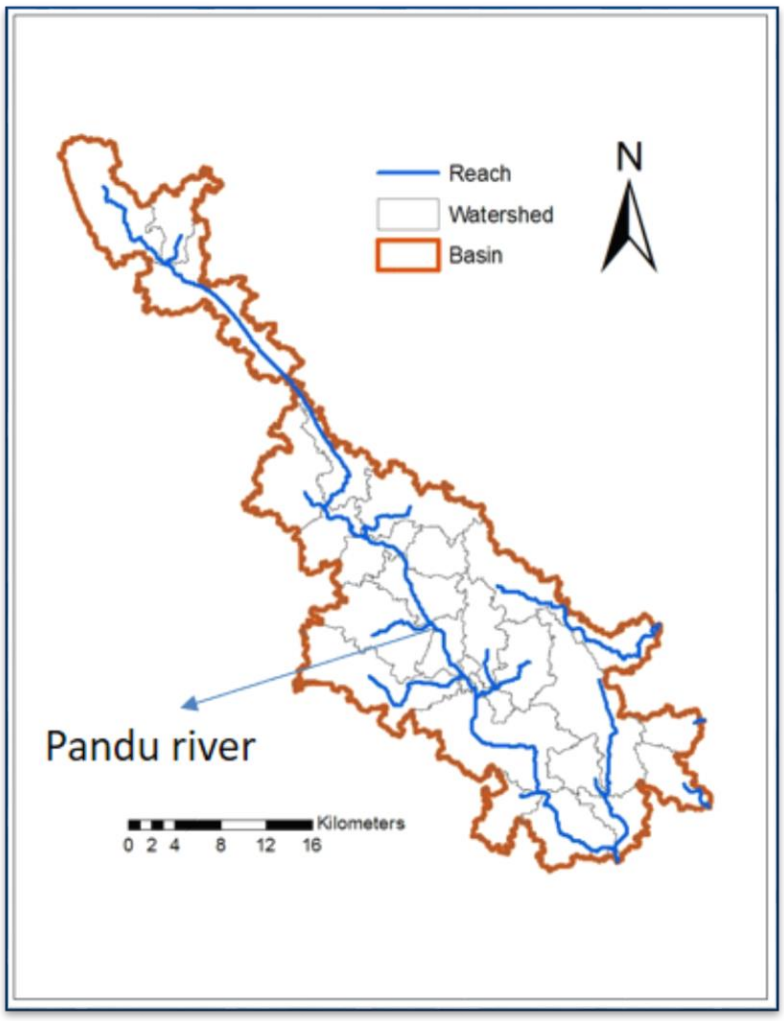


Figure 12: Delineated watershed in Kanpur Nagar district

I. Kanpur

- **Industrial belt:** In the industrial belt of Kanpur Nagar, the main stream is a tributary of Ganga called river Pandu as represented in Figure 12. It runs parallel to the river Ganga and touches the southern border of Kanpur. There are four drains that collectively drain Kanpur's waste water into to the river Pandu.

- **Water balance:** The water balance parameters estimated from model using LULC for the year 2006 and 2016 is shown in the Table 3. The **hydrological parameters of the delineated watershed was evaluated using two LULC maps from different time period.** The LULC map of 2006 and 2016 were used for the two simulation run. The observations from the year 2009 to 2013 were considered as these were the overlapping years with respect to the LULC maps (2006 and 2016). The output from these overlapping years provided

The hydrological parameters used in the model

- Potential evapotranspiration(PET)
- Evapotranspiration(ET)
- Surface run-off
- Lateral flow
- Groundwater flow

insight about impact of change in the LULC on run-off and infiltration rate of the study area. The data from 2009 to 2013 were taken as the common years. This is because the central year lies between these years and there has been an increasing rainfall trend between these years ranging between 843 mm to 1410 mm.

- **Surface run-off, ground water recharge and evapotranspiration**: Estimated surface run-off has increased and groundwater recharge has decreased from 2009 to 2013 as showcased in Table 3. Importantly, the decline in groundwater could have serious impact if the trend continues, as this is the main source for irrigation amounting to 74% in the Kanpur Nagar (DPC, 2008). However, there has not been much change in PET and ET suggesting the current increase in urban area at the cost of vegetation does not have much impact in evapotranspiration. Most of the area is still under agriculture activity in the basin; therefore, the run-off from the basin has not seen a substantial increase.

Table 3: SWAT output of Kanpur watershed

Year	LULC maps	Rainfall (mm)	SurQ (mm)	GWQ (mm)	ET(mm)	PET (mm)
2009	2006	843.7	151.6	319.12	299.76	1445.17
	2016		162.2	310.12	298.85	1445.17
	Difference		**10.6**	**-9**	**-0.9**	**0**
2010	2006	988.2	178.79	434.61	309.24	1415.24
	2016		191.34	423.19	308.57	1415.24
	Difference		**12.6**	**-11**	**-0.7**	**0**
2011	2006	1122	249.22	474.62	337.13	1291.93
	2016		263.07	462.06	336.25	1291.93
	Difference		**13.9**	**-13**	**-0.9**	**0**
2012	2006	1100	254.16	507.22	271.83	1422.77
	2016		268.9	493.55	271.45	1422.77
	Difference		**14.7**	**-14**	**-0.4**	**0**
2013	2006	1410	288.33	668.65	364.22	1220.8
	2016		306.55	651.27	364.22	1220.8
	Difference		**18.2**	**-17**	**0**	**0**

II. Hardoi

- **Watershed in agriculture belt:** There were three watersheds delineated in agriculture belt in Hardoi district and Mohammadi tehsil of Lakhimpur Kheri based on hydrological patterns and topography of the region. With respect to the four villages under the study area, Korigawan

comes under watershed I, Semarghat under watershed 3 whereas the two villages of Barkhani and Kazibari come under watershed 2.

- **Watershed in agriculture belt**: There were three watersheds delineated in agriculture belt in Hardoi district and Mohammadi tehsil of Lakhimpur Kheri based on hydrological patterns and topography of the region. With respect to the four villages under the study area, Korigawan comes under watershed I, Semarghat under watershed 3 whereas the two villages of Barkhani and Kazibari come under watershed 2.

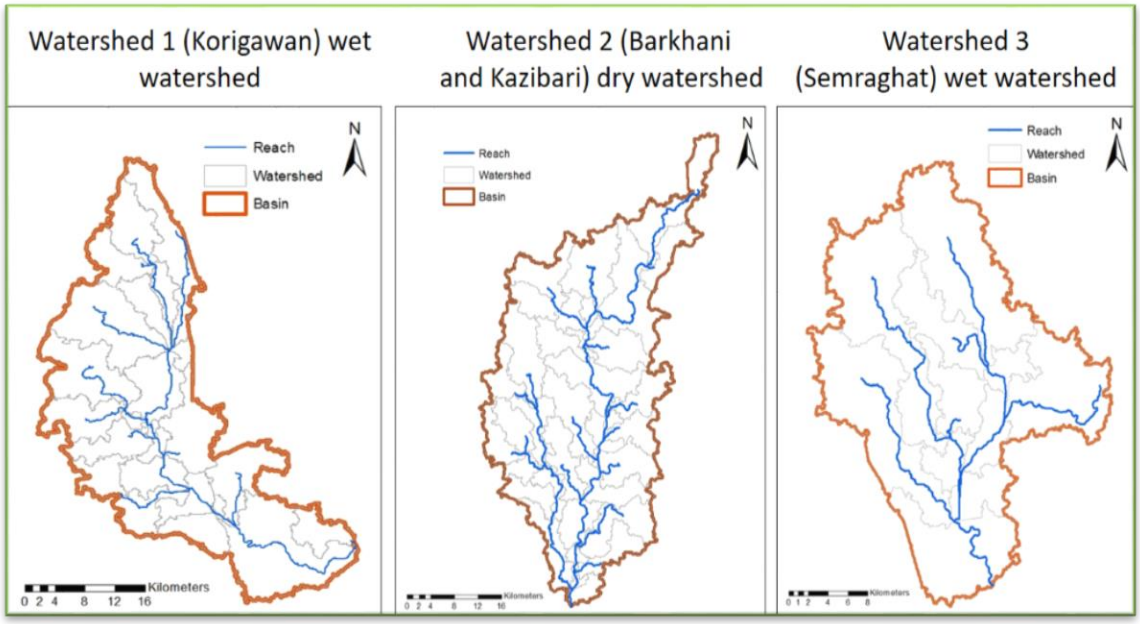


Figure 13: Delineated watershed in Hardoi district

- **Water balance**: The watershed with two villages is a dry watershed, as it lies on the western side of the Hardoi region. The hydrological parameters estimated for the three watersheds from the model are given in Table 4, 5 and 6. Using the same method for evaluation as executed in the Kanpur district, the analysis was carried out for overlapping years of 2009 – 2013. From the three tables, there is an **increase in the runoff potential in the three watersheds**.
- **Surface run-off, ground water recharge and evapotranspiration**: Similar to Kanpur Nagar district, there is also **decline in groundwater recharge potential of the area.** These changes in surface run off and groundwater recharge potential could be attributed to the **increase in fallow land and decline in vegetation cover in this region**. The decline in the vegetation cover could be also responsible for the **decrease in the overall evapotranspiration in the area** that can also be seen from the SWAT simulation.

Table 4: SWAT output for Hardoi watershed 1

Year	LULC maps	Rainfall (mm)	SurQ (mm)	GWQ (mm)	ET(mm)	PET (mm)
2009	2002	817.2	127.77	307.49	315.1	1414
	2016		139.86	298.73	307.4	1408
	Difference		**12.09**	**-8.76**	**-7.7**	**-6.3**
2010	2002	778.1	98.98	308.37	310	1353
	2016		109.54	300.85	302.5	1347
	Difference		**10.56**	**-7.52**	**-7.5**	**-6.1**
2011	2002	1162.7	209.94	522.47	338.7	1245
	2016		229.12	508.63	331.7	1239
	Difference		**19.18**	**-13.8**	**-7**	**-6.5**
2012	2002	916.4	186.11	395.86	269.1	1450
	2016		200.72	385.41	261.4	1444
	Difference		**14.61**	**-10.5**	**-7.7**	**-5.8**
2013	2002	1410.3	174.95	559.99	409.5	1209
	2016		194.01	546.12	403.9	1204
	Difference		**19.06**	**-13.9**	**-5.6**	**-5.4**

Table 5: SWAT output for Hardoi watershed 2

Year	LULC maps	Rainfall (mm)	SurQ (mm)	GWQ (mm)	ET(mm)	PET (mm)
2009	2002	792.8	65.12	324.83	311.77	1428.4
	2016		77.46	314.9	308.6	1426
	Difference		**12.34**	**-9.92**	**-3.18**	**-2.7**
2010	2002	1015	48.51	496.91	337.49	1389.9
	2016		65.21	484.36	334.33	1387.33
	Difference		**16.7**	**-12.55**	**-3.16**	**-2.57**
2011	2002	1144	121.5	552.4	358.5	1280
	2016		142.5	535	355.7	1277
	Difference		**21.05**	**-17.4**	**-2.79**	**-2.78**
2012	2002	798.7	50.26	377.5	282.4	1436
	2016		63.31	367	279.2	1433
	Difference		**13.05**	**-10.51**	**-3.2**	**-2.61**
2013	2002	1281	78.66	627.3	417.7	1230
	2016		99.22	610.6	415.8	1228
	Difference		**20.56**	**-16.74**	**-1.9**	**-2.26**

Table 6: SWAT output for Hardoi watershed 3

Year	LULC maps	Rainfall (mm)	SurQ (mm)	GWQ (mm)	ET(mm)	PET (mm)
2009	2002	817.2	134.42	293.23	314.01	1404.16
	2016		141.6	286.6	314.8	1405
	Difference		**7.21**	**-6.64**	**0.78**	**0.59**
2010	2002	778.1	105.1	298.53	307.57	1343.56
	2016		111.42	292.59	308.26	1344.13
	Difference		**6.32**	**-5.94**	**0.69**	**0.57**
2011	2002	1163	222.3	502.4	343.9	1235
	2016		233.8	491.6	344.7	1236
	Difference		**11.49**	**-10.78**	**0.86**	**0.61**
2012	2002	916.4	196.68	379.26	269.18	1441.1
	2016		205.4	371.1	270	1442
	Difference		**8.68**	**-8.18**	**0.85**	**0.55**
2013	2002	1243	182.5	544.2	413.5	1201
	2016		194	533.2	414.4	1201
	Difference		**11.55**	**-10.96**	**0.84**	**0.51**

2.4 Conclusions

The results of this study carried out to understand the implication of increase in industries and sugarcane in the mid-Ganga river basin suggest that the change in land use/land cover have significant impact on the current water resources. In both industrial belt as well as sugarcane belt there has been increase in surface run off and decline in ground water recharge due to decline in total vegetated cover.

Specifically, in Kanpur district, there has been increase in urban area and decline in cultivated land over last one decade. The overall loss in vegetated land for urban expansion has led to decline in groundwater recharge capability of the area. Although currently not so significant, but the increase in surface run-off and decline in ground water recharge if continued could have serious impact on agricultural activities as groundwater is the main source for irrigation amounting to 74% in the Kanpur Nagar. The condition becomes more serious as there has been substantial decline in the groundwater table due to the excessive withdrawal for irrigation as there is no canal network in the area and industrial use where around 400 leather tanning industries withdraw groundwater for

their processing operations. Therefore, there is need to put effort in the direction of development of green belt around Ganga.

In Hardoi district and Mohammadi tehsil of Lakhimpur, most of the land use/land cover transition have occurred in the western part of the region that lack proper canal network and groundwater resources. In general loss of vegetated cover and increase in fallow land in the study area have led to relative increase in the runoff potential and decline in groundwater recharge in all the three watersheds due to reduction in soil infiltration capability. Moreover, there has been a decline in the water bodies that were present in the southern tehsil of the Hardoi district. Therefore, extension of canal in western part and revival of waterbodies could be considered in this study site.

Chapter 3
COMMUNITY RESOURCE INTERACTIONS

3.1 Introduction

The basic premise of this study is that the middle reaches of the Ganga are gradually yielding to the development pressures (such as land use changes, resource extraction and pollution). The declining flow and quality of water sought recourse in severe regulation; however, the outcomes were not encouraging.

This study tries to understand the interaction between the ecosystem and the socio-economic systems and suggest that the tradeoffs must be carefully negotiated based on proper understanding of socio-economic context, pressure on the water resource, resource allocation, resource use efficiency and the institutional framework.

Situating within the landscape approach, this chapter tries to understand the socio-economic condition of the two productive belts along the Ganga river basin-that of Kanpur and Hardoi/Lakhimpur. Hardoi district is marked by primarily agrarian economy where farmers cultivate sugarcane, wheat, vegetables, pulses and oilseeds. Characterized by loamy soil and marked by presence of Sharda canal and good groundwater level, this fertile belt has thriving network of sugar mills. In the last ten years, the number of sugar mills and area under sugarcane cultivation has increased. Agriculture is supported by allied activities along with migration/labour in non-agricultural season.

Kanpur is spilt into two administrative units: Kanpur Nagar and Kanpur Dehat. Popularly known as the *leather city* with over 400 leather tanneries and more than double household units most of the leather products from Kanpur Nagar are exported. While the tanneries are concentrated in *Jajmau* area, the discharge from these tanneries has become a massive concern for water quality in this belt of Ganga. Kanpur Dehat, as the name denotes has population concentrated in rural parts. More than 80% of the population consists of cultivators, mostly of sustenance nature since the land holdings are fragmented. Agriculture is supported by allied activities like animal husbandry and labour.

As stated earlier, the choice of study area was based on three sets of parameters- land use/land cover change; hydrological and socio-economic condition. **The reason for concentrating on two**

pockets was to be able to capture two powerful pockets of intensive agricultural use and extensive industrial corridor, especially the leather industry that is a source of massive pollution. Along with the socio-economic profile, the chapter also examines the community-resource interaction (with focus on water resources), resource management practices, gender-resource relationship. The analysis synthesizes these findings to understand the drivers for pressure on natural resource (particularly water) and the risk preparedness of the communities in these areas.

3.2 Methodology

The mixed method approach was used to collect data on socio-economic and gender aspects.

- **Primary data** was collected using short surveys, semi-structured interviews, PRA techniques, focus-group discussions and non-participant observation. Expert interviews included interview with the CETP officials, irrigation department officials, officials from the sugar mill and the village sarpanch.
- **Secondary data** included Census data, Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) reports on water quality issues in Ganga, study reports etc.
- **Respondents (sample):** Purposive sampling was done to categorize the respondents on dimensions of occupation, caste and gender. The respondent profile for Hardoi and Kanpur are as follows:

Categories	Hardoi	Kanpur
Total farmer respondents	48 Other Backward Classes (OBC) -28; General-11; Scheduled Caste (SC) - 8	44
Total Non-farmer respondents	18	14
Total female respondents	28	15

A. **Focus group discussions** were carried out with the farmer groups and the women respondents to capture the following:

i. Agricultural practices and water use practices
ii. Changes in cropping pattern
iii. Institutional support for agriculture; and,
iv. Gender dynamics with reference to '***women - natural resource'*** interaction and women's participation in decision making at the household and community level.

The data was analyzed based on occupational categories to understand the community resource interactions and institutional dynamics. Gender dynamics and aspects of gender-resource interaction were captured separately. The findings and analysis will be presented in the following section under the following broad thematic categories:

Broad thematic categories and aspects covered (variables used)		
Physical infrastructure	➢ Settlement pattern (house type) ➢ Roads & electrification ➢ Water sources	➢ Waste management (infrastructure and use) ➢ Toilets
Social infrastructure	➢ Education, health ➢ Conflict resolution ➢ Kinship ties	➢ Institutional credit facilities (banks or other financial institutions, moneylenders)
Livelihood and resources	➢ Land holding, livestock & other asset ➢ Costs and prices, wage rates/income earned ➢ Food security and consumption, natural resources availability like pastureland, ponds etc.	➢ Occupation
Institutional infrastructure	➢ Rules and regulations pertaining to village administration and resource management ➢ Presence of self-help groups and other such community institutions	
Gender & caste dynamics	➢ Gender division of labour ➢ Participation in workforce ➢ Institutions and decision making	➢ Socio-economic well-being

Figure 14: Thematic areas and aspects covered

3.3 Findings from Hardoi

A. Physical Infrastructure

i. **Settlement pattern:** The settlement pattern amongst the households showed that most of the farmers of the general and the OBC categories lived in *pukka* (P) and *semi-pukka* (SP) houses but the SC families were living in *kuchcha* (K) houses. The pattern was similar across farmer and non-farmer households.

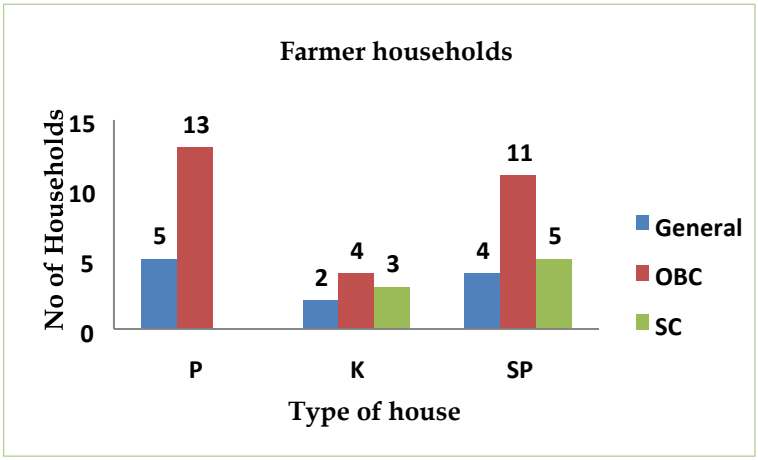


Figure 15: Settlement pattern-house type in Hardoi

ii. **Sanitation and waste/wastewater management:** Most of the farmers from general category and few from the OBC category had access to toilet facilities and used toilets in their households. Rest of the households are still practicing open defecation. Where constructed, the toilets were of pour flush types, without piped water facility (see figure 16 for access to toilets among farmer community).

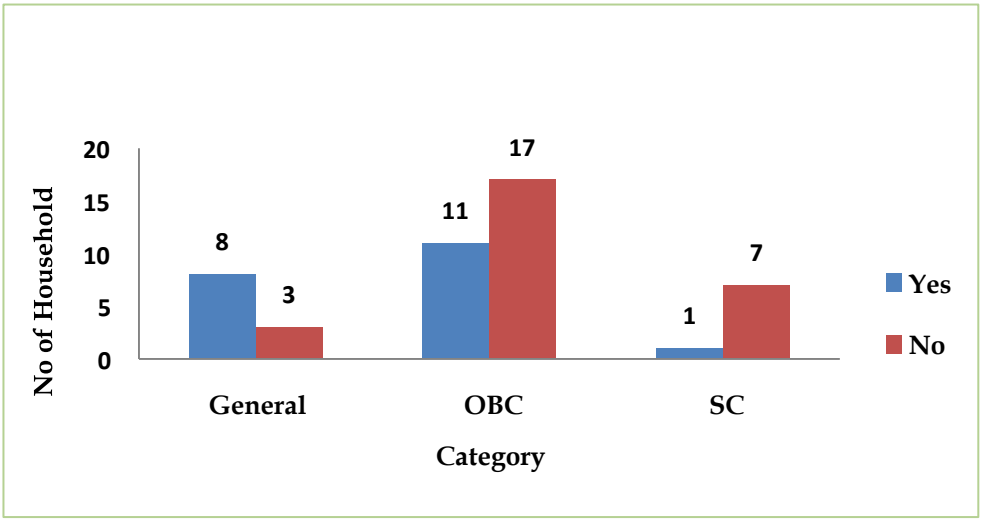


Figure 16: Access to toilet facility in Hardoi

Only one third of the non-farmer respondents had constructed toilets and were using it. The rest defecated in the open. Kitchen waste was normally fed to the livestock or composted in some cases. The waste water was indiscriminately discharged to open drains, agricultural plots, ponds or streams (see figure 17).

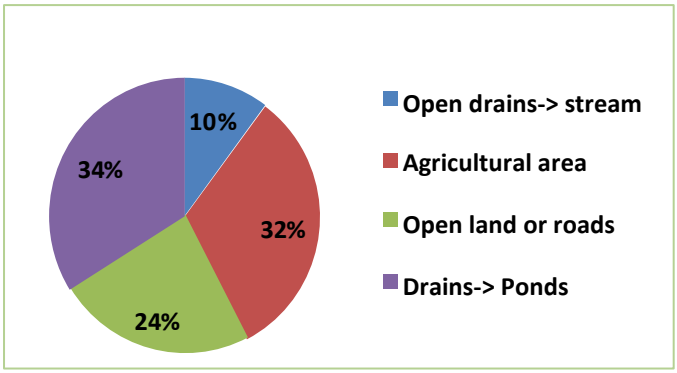


Figure 17: Waste water discharge in villages in Hardoi

iii. **Water source:** All households (both farmer and non-farmer households) abstracted groundwater for domestic use; almost 80 % using self-installed handpump while the rest used the government installed handpumps. **Not many issues were raised regarding the water quality, except five respondents in Kazibadi and Bharkhani who felt that the groundwater quality has declined in last five years and was unsuitable for drinking.**

iv. **Roads and Electrification status:** Most of the village roads were unmetalled and in poor condition. Semarghat, Bharkhani and Korigawan were electrified but the supply in first two villages was erratic. On the other side, Kaziwadi was still unelectrified. Thus, most of the households in Kaziwadi and Semarghat used solar panels for lighting and operating other household appliances like fans and mobile charging purposes. A five-watt solar panel cost approximately INR 600 in the open market.

B. Social infrastructure

i. **Education**: Almost 62% of the farmer respondents were either uneducated or were primary school drop outs. The rest had continued education till high school or pre-college. The situation was similar amongst the non-farmer households, where the proportion of uneducated individuals was much higher. All the villages had functional primary schools; while Bharkhani also had a girls' school and a higher secondary school. Few students from Bharkhani also attended private school in Pali, Anangpur and Shahabad. Semarghat had a private school run by the Sikh community, which appointed private teachers.

ii. **Health:** Access to state health care services was poor in all the villages. Not only were the primary health center's (PHCs) and government hospitals distant (except Bharkhani that was a Panchayat village) but the quality of services (availability of doctors, medical equipment's, patient care, diagnosis and treatment) was also far from satisfactory. Only 37% of the farmer and non-farmer respondents used Government facilities (by choice), where almost 50% were not satisfied with the treatment. Thus, 63% of the farmer and non-farmer respondents chose private health care facility. **Only nine respondents out of 63 farmers and non-farmers (14%) had medical insurance.**

iii. **Incidence of disease:** Almost 45% of the respondent farmer households suffered from various diseases in the last one year and availed treatment. The most common diseases include malaria, jaundice, tuberculosis, diabetes, arthritis, heart problems, thyroid, stone, diarrhea and blood pressure**.**

- The incidence of disease was higher among the non-farmer respondents, where almost two third of the respondent households suffered from diseases in the last one year.
- The nature of disease included high blood pressure, cardiac issue, kidney stone, gastritis, brain disorder, malaria, typhoid, dengue, polio, hernia, tuberculosis and chicken pox.
- The higher incidence could possibly be explained by lower socio-economic status and labour migration related mobility. Incidence of water-borne diseases also related to poor sanitation and waste management facilities.

iv. **Conflict resolution:** 43% of the farmer respondents and 68% of the non-farmer respondents explained that they resorted to police station to settle disputes. Only 15% of the total respondents (including farmer and non-farmers) mentioned the role of Panchayat in dispute resolution. Rest of the respondents cited mutual/intra-village settlement.

v. **Culture and kinship ties:** The villagers cited strong kinship ties and instances of celebrating various festivals including *Holi, Dussehra, Diwali, Raksha Bandhan, Bhai Duj* etc. and *Eid* and *Muharram* in Kazibadi which also had Muslim community; while also helping each other in times of need. The family type did not show any regular pattern with villages having both joint and nuclear families. However, caste based discrimination was evident in social interactions in the village (particularly in Bharkhani and Semraghat).

C. Livelihood and resources

i. **Occupation:** *Primary occupation* of all the respondents was either agriculture or labour or both. *Secondary sources* of income included business, service, animal husbandry pension (in few cases). Labour based migration was rampant amongst the landless families where only the male member of the household migrated to work primarily in the construction or transport sectors.

ii. **Land holding:** The average land size among the farmers varied from 11 acres among the general category farmers to one acre among the SC. The general category farmers were thus large farmers, while the SC farmers were marginal farmers. Most of the OBC category farmers were small farmers with average land holding of four acres. This excluded exceptional cases where the farmers possessed over 20-30 acres of land. This was mostly amongst the Sikh farmers in Semarghat and general caste farmers (in few cases). However, the average land size of the farmers is approximately five acres.

iii. **Household assets:** The most common assets at the household level in the villages included mobile phones, bicycles, pump sets. Assets like television, refrigerator, washing machine inverter and cars, were uncommon (see figure 18 for farmer household assets). The farmers of the general category were better off than the OBC and the SC community in terms of household assets. Most of the households in general and OBC category were equipped with tractors, pump sets and motorcycles along with mobile phones. Very few households had cars, washing machines, refrigerators and/ or televisions. The SC category farmers had mobiles and bicycles. The SC farmers did not have other assets like washing machine, refrigerator, tractor, solar panels, television and/or car.

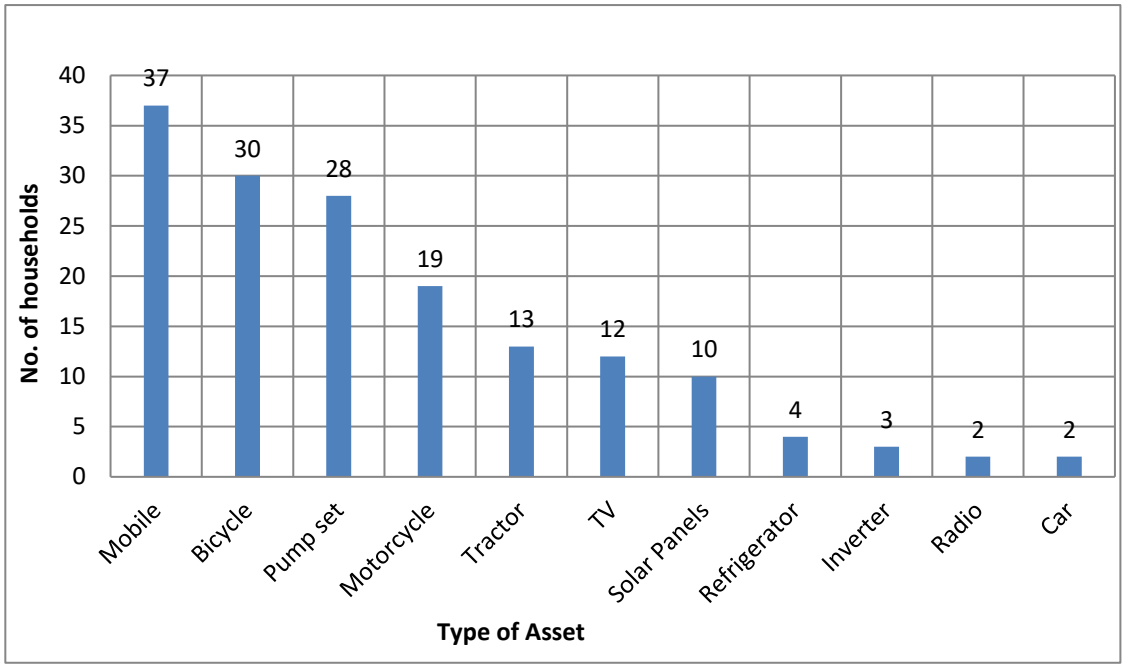


Figure 18: Asset holding of farmers in Hardoi

iv. **Livestock holding:** Livestock included mostly cows and buffaloes amongst both the farmer and non-farmer households. Table 7 and Table 8 illustrate the livestock details, along with average consumption of water and expenditure on fodder. Livestock was sold during the festive season and served as a good risk cover. Milk from the livestock was not sold in most cases except in Semarghat where they sold milk produce to the local dairy.

Table 7: Livestock holding among farmer households in Hardoi

Livestock	No. of household	Total no. of livestock unit	Average water consumption (per day per unit in litres)	Average monthly expense on fodder (per unit in INR)
Cow	20	29	27	1800
Buffalo	28	52	63	2000
Bullock	1	2	50	750
Goat	2	4	6	750

Table 8: Livestock holding among non-farmer households in Hardoi

Livestock	No. of household	Total no. of livestock unit	Average water consumption (per day per unit in litres)	Average monthly expense on fodder (per unit in INR)
Cow	7	13	22	1450
Buffalo	4	6	41	2100

v. **Income:** The average annual income of farmer household from farming was highest from service, followed by livestock (although these were exceptional). The average annual income from farming was approximately INR 1,67,769. However, this was subject to the land holding of the farmer.

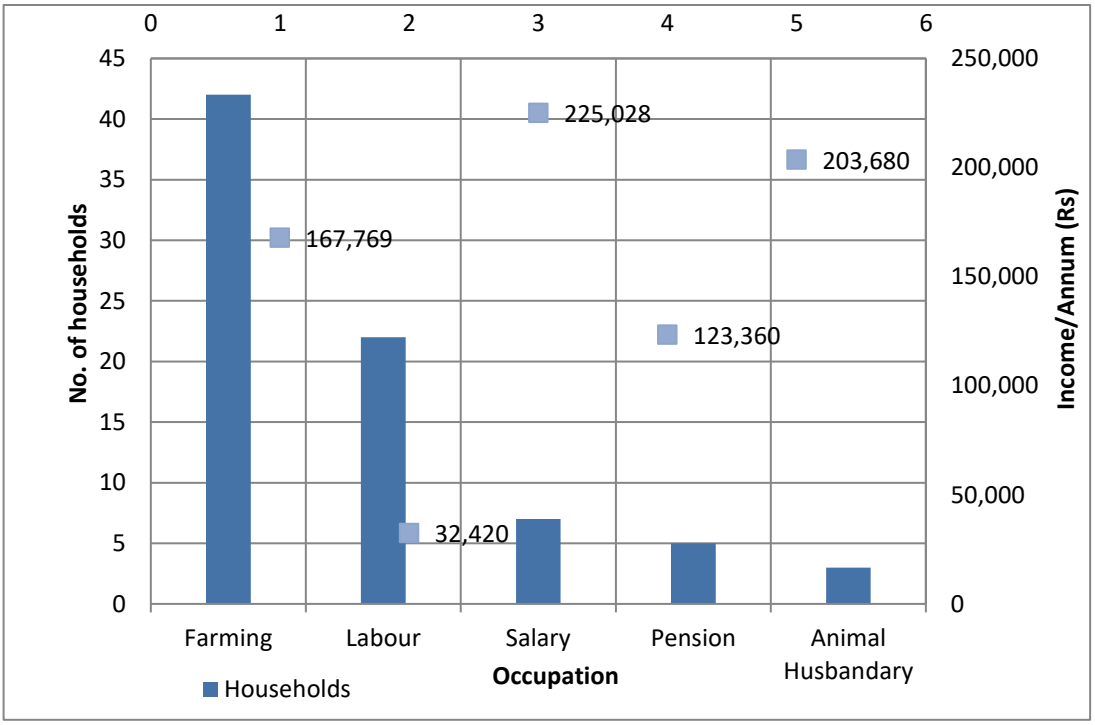


Figure 19: Income of farmer households in Hardoi

The average annual income was much higher for households that were in business or service (non-farmer households). Figure 20 shows the income for non-farmer households.

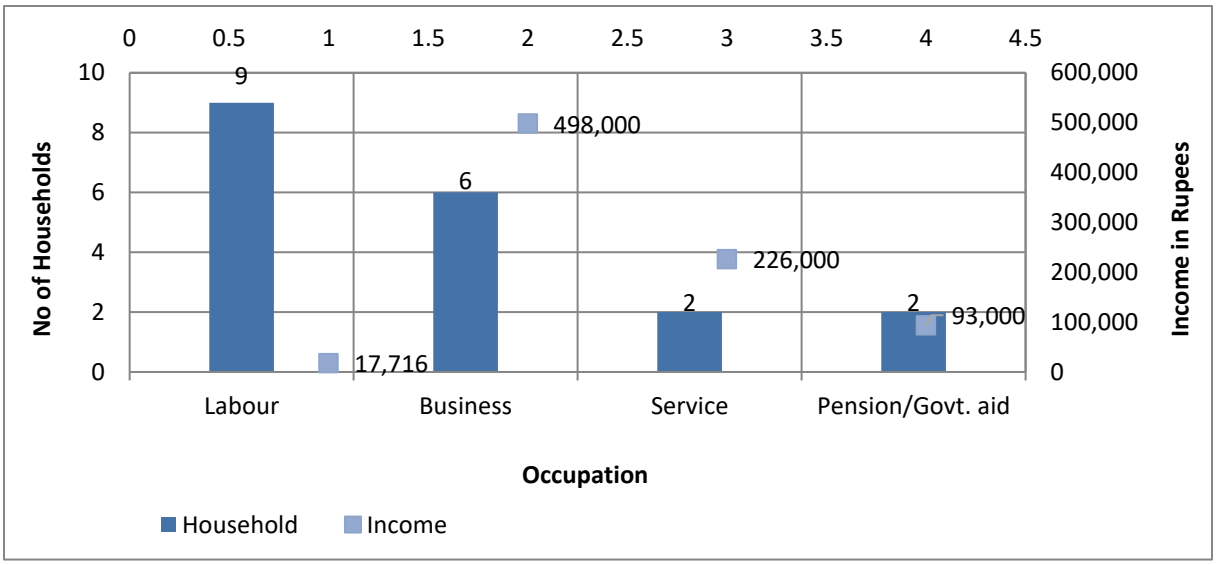


Figure 20: Income for non-farmer households in Hardoi

vi. **Expenditure:** The average annual expenditure was highest on food items for both farmer and non-farmer groups. The variation between the farmer and non-farmer groups was seen with respect to festivals, health and transport. While the farmer households spent considerable amount of money on festival. and transport (mostly for transport of agricultural produce), the non-farmer households spent more money on health and less on festivals). Non-farmer households also reportedly spent a lot on liquor consumption (see figure 21 and 22).

A caste wise break up of expenditure pattern (see figure 23) shows that the general category farmers spent maximum while expenses of SC category farmers were the least. The SC farmers did not pay for electricity.

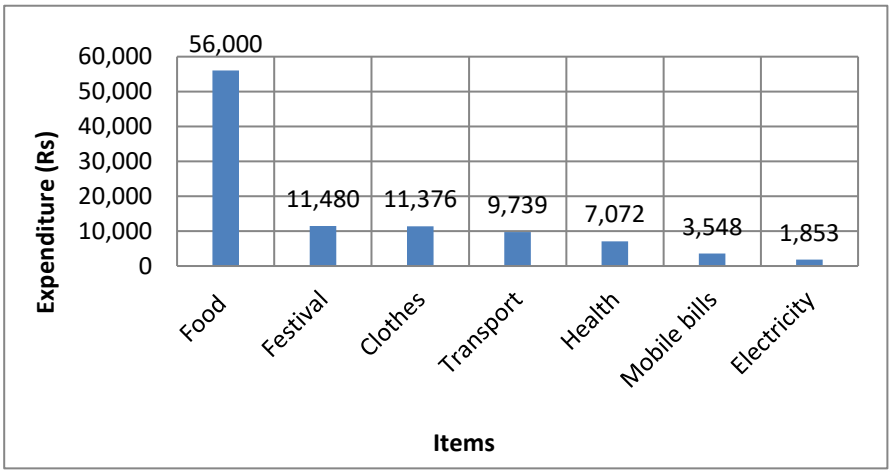


Figure 21: Average annual household expenditure (farmer) in Hardoi

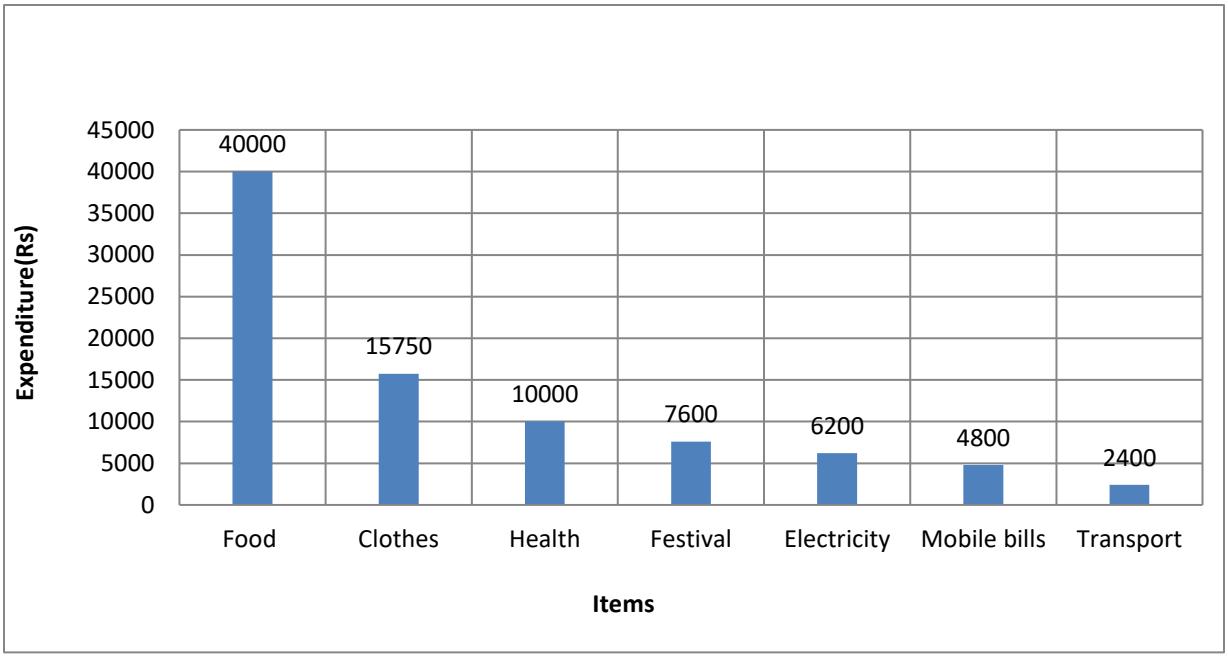


Figure 22: Average annual household expenditure (non-farmer) in Hardoi

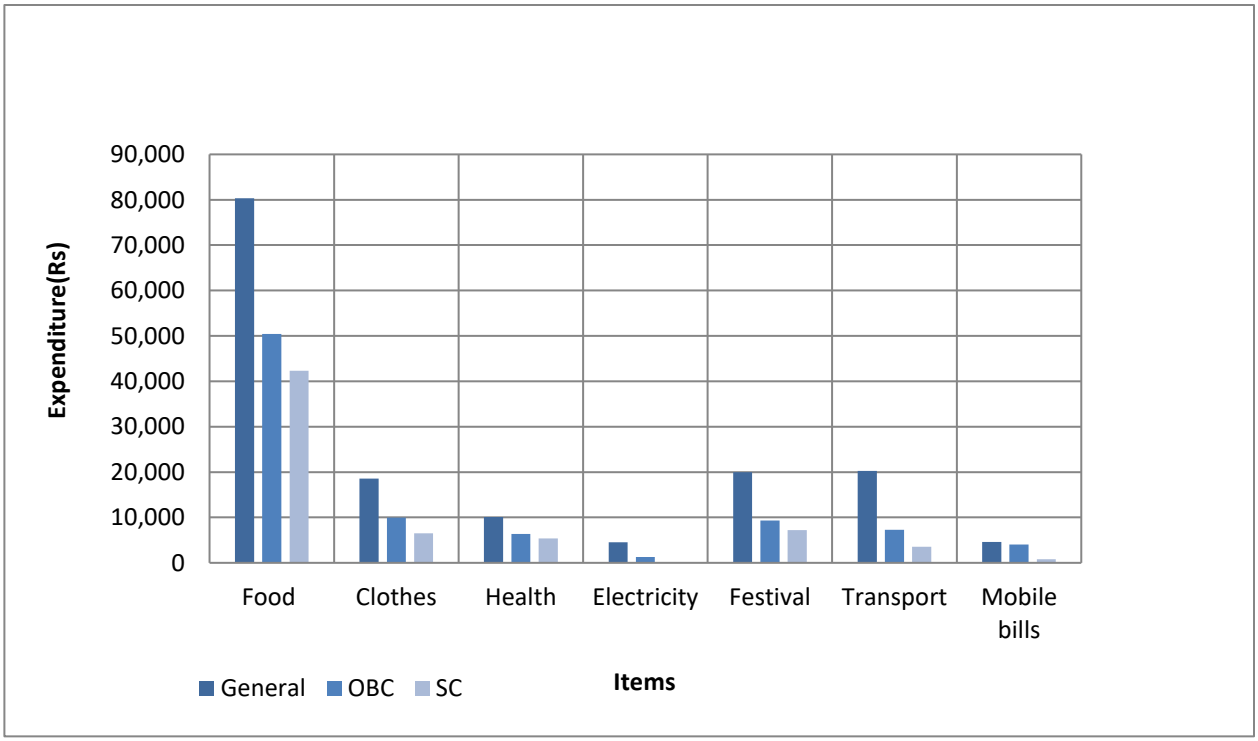


Figure 23: Caste-wise expenditure pattern among farmer households in Hardoi

vii. **Savings**: Only 50 to 60% of the respondents said that they could save money. Those who did, kept their savings in the bank. Only one non-farmer respondent invested in shares.

viii. **Loan**: Over 60% of the respondents had availed loan. While farmers availed agricultural loan and personal loan, the non-farmers mostly availed loan for business purposes or to install solar panel (other than personal loan). Productive loans were mostly availed from the bank while consumptive needs were met by the moneylenders (who were mostly the large farmers in the village). Figure 24 shows the lending pattern among the farmer respondents.

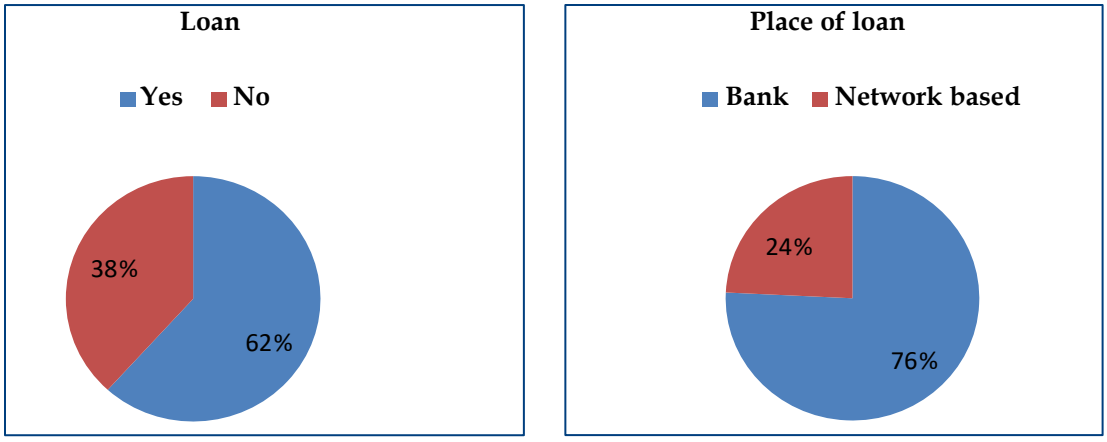


Figure 24: Lending pattern among farmer respondents in Hardoi

ix. **Crops grown:** Most of the farmers cultivated wheat while few cultivated sugarcanes. A total of 15 out of 47 farmers were growing both wheat and sugarcane. While wheat was considered as a safe crop to at least meet the household consumption requirements, there was considerable interest amongst the farmers for switching to sugarcane because of assured prices and relatively high profitability. Figure 25 depicts the choice of crops among the farmer respondents.

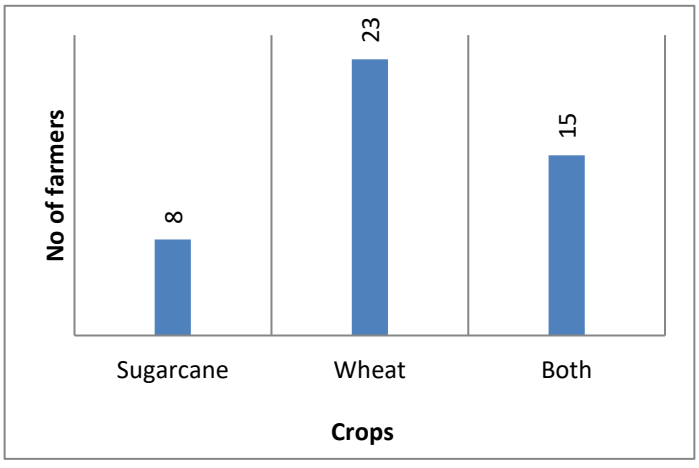


Figure 25: Choice of crops among farmer households in Hardoi

x. **Input Cost for crops and crop productivity:** Input cost includes the cost of seeds, pesticides, fertilizers and energy (diesel). Since the farmers use family labour, it is not included in cost. The input cost per acre for wheat and sugarcane was INR 4895 and INR 17500 respectively. Total revenue for wheat and sugarcane per acre was INR 17500 and INR 94500 respectively. It needs to be considered that while wheat is a seasonal crop (four-five months' cycle), sugarcane is an annual crop (eleven-twelve months' cycle). Figure 26 and 27 below depict the variation in the input cost and revenue for the two main crops.

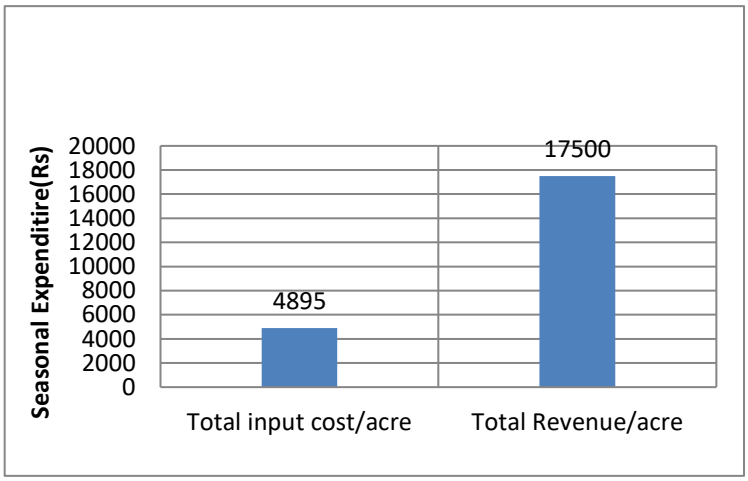


Figure 26: Input and revenue cost for sugarcane (Hardoi)

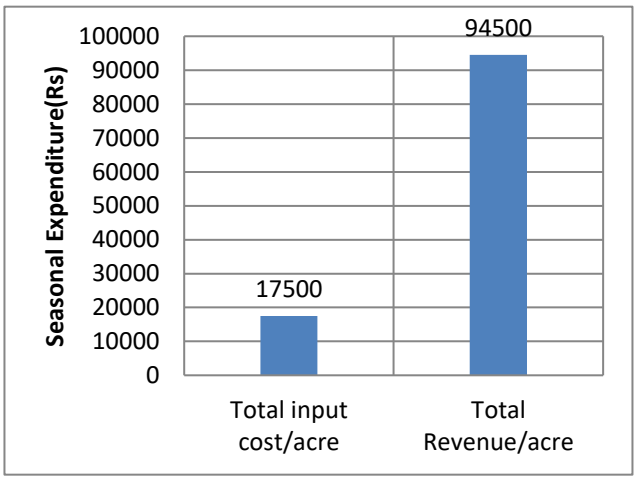


Figure 27: Input cost and revenue for wheat (Hardoi)

xi. **Crop insurance:** Farmers were found vulnerable to various climatic stresses. Only 19% of the farmers had crop insurance, rest of the 81% did not have any kind of insurance of the crops.

xii. **Irrigation cycle**: While the crop productivity and revenue is higher in sugarcane, farmers also explain that it is more water intensive. Every crop requires almost 8-10 cycles mostly during late winter/early summer of irrigation and the crop productivity stands at almost 300 quintals per acre. At the same time, wheat requires 4-5 irrigation cycles and the crop productivity stands at 12-15 quintals per acre. In absence of proper irrigation facility and provision of subsidized electricity, mismanagement of resources was common. Thus, in certain electrified villages, farmers irrigated the plots as long was electricity supply was available. Table 9 shows the irrigation requirement for the two crops.

Table 9: Irrigation requirement for wheat and sugarcane (Hardoi)

Crops	Duration Seasonality (months)	Irrigation cycle	Crop Productivity (quintal/acre)
Sugarcane	12	8-10	300
Wheat	4	4-5	12-15

xiii. **Sale of crops:** While wheat was sold directly at market price determined by local mandi/market, sugarcane was procured by sugar mills at fixed rate, depending on the cane quality. Only three farmers (among the respondents) were reported to sell their crops through middlemen.

xiv. **Energy source (cooking fuel):** Most of the farmer and the non-farmer respondents used fuelwood for cooking in combination with dung cakes. LPG connection was a rarity and even if the household had a connection, they preferred using a combination of biomass and LPG to save cost.

D. Institutional infrastructure

i. **Local institutions:** The villages had no functional institutions other than the Panchayat. The governance of the Panchayat was ridden with several problems as listed below:

- Two thirds of the respondents perceived the Panchayat to be ineffective. Rest stated that they attended the meetings with minimal participation.
- Most of the respondents perceived the leadership as weak and discriminatory. Institutions were also marked by caste discrimination in multi-caste villages
- No/minimal participation of women in Panchayat meetings and functioning (only five households stated that they attended the meetings)

ii. **Awareness about government schemes and activities:** Most of the respondents were aware about Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and Pradhan Mantri Jan Dhan Yojna and had availed benefits from these schemes. Some of the respondents were also aware about the schemes like Krishi Vikas Yojna, Pradhan Mantri Suraksha Bhima and Rajiv Awas Yojna.

iii. **Conflict and cooperation:** Conflicts in the village were mostly resolved within the village or escalated to the police. Figure 28 depicts the dispute resolution pattern within the study villages. Villagers cooperated with each other under stress, however, no strong organizational or network ties were evident in any village.

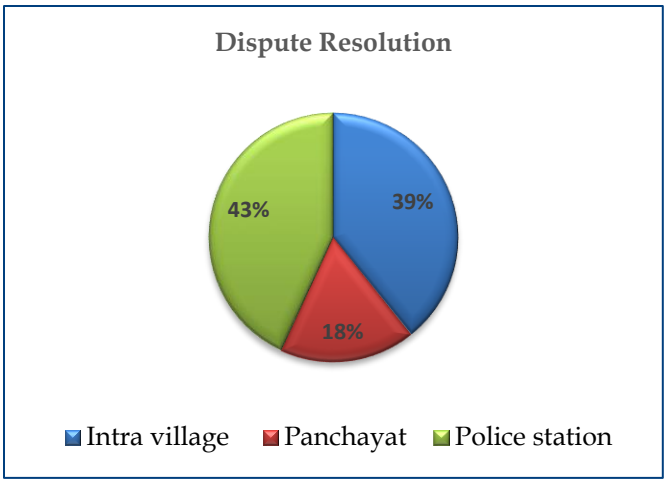


Figure 28: Dispute resolution (Hardoi)

E. Gender dynamics

To understand the gender dynamics 44 women respondents from all caste groups were interviewed. Few focus group discussions were also conducted to understand gender roles, decision making and gender-resource interaction.

i. **Family type:** The general category women were mostly part of joint families while OBC and SC category women were from the nuclear families, representing the normal trend.

ii. **Cultural dynamics/gender stereotypes:** Women from all categories practiced purdah (veil) system. Women from general category could not freely express their views in front of the male members. Women from OBC category could voice their concerns in front of the male members.

iii. **Education:** Most of the women were uneducated. Few had studied till primary, middle or high school levels, while there were two graduates amongst the 44 respondents. Girls/women discontinued education due to family pressure or financial crisis. However, all young mothers showed interest in educating their girl child.

iv. **Access to space and sanitation facilities**: Most of the families, especially among the OBC and SC categories; lived in small spaces. Therefore, questions pertaining to access to separate space for women seemed unfounded. While most of the general category women had access to toilet and bathing space, women from OBC and SC categories still defecated in the open.

v. **Access to health institutions:** Most of the women of the older generation, especially among the OBC category, had home deliveries. Currently, there is better access to institutional delivery. Yet, all the women are not able to use this facility. For rest of the illnesses, households preferred private clinics over public hospitals or health centers.

vi. **Access to marketplace:** Women's access to market was very restricted. Only few OBC women stated that they went to market to buy certain goods but were always accompanied by male members of the family. Women did not have any role in financial transactions/market transactions. Women were unaware about the market trends and crop rates, except few OBC and SC women.

vii. **Participation in workforce:** Few women from OBC category and SC category worked as labour but women from general caste were not part of the workforce.

viii. **Ownership of property:** Women did not own any property. Only 50% of women respondents were even aware of the actual landholding of the family.

ix. **Gender role:** Work related to agriculture and financial planning were mostly carried out by male members of the household (except in SC category where women participated in the agricultural activities). Household chores including cooking, cleaning, washing utensils and clothes, child rearing, animal rearing was mainly done by women of the households. Household finances were mostly in the purview of the male members (especially among the OBC category).

x. **Household decision making:** Decisions pertaining to education of children, household expenditure, marriage and family planning was mostly done by both male and female members of the households. However, women did not have any say in decisions pertaining to resources, like property, crop choices, savings and investment.

xi. **Women's participation in governance:** While women find very little space in decision making role at the household level, the representation and participation in village governance is dismal. Only one village (Bharkhani) had a woman Sarpanch. However, the functional office was held by her husband. The participation was lowest among the SC member, who also faced severe caste discrimination. Most of the women did not participate in Panchayat meetings. In cases of conflict,

matters were resolved at the household or village level through discussion. However, a few among the SC and OBC categories reported having escalated the case to police station.

3.4 Findings from Kanpur

Village location and settings

There were five villages under Aima GP- Aima, Karbi, Gadhyampurva, Bagaicha and Karankhera. Out of these, the first three were selected for this study to represent major caste groups (see figures 29, 30 and 31 for social and resource maps of villages). The village maps showed that the village was heterogeneous and the caste groups were in clusters in different villages. Gadhyampurva primarily had OBC settlement. The villages were connected to the main road through metaled roads but the roads within the village were unmetalled. There were four schools in the village. The male female ratio in the population was 53:47. Literacy level among female (67%) was lower than male (85%) population. Agricultural fields were on the outer edges of the village or the settlement in in the village core. There were multiple ponds in the village but most of it was either filled with waste or had dried up in absence of maintenance. There was a considerable number of hand pumps also

Figure 29: Social and resource map of Karbi

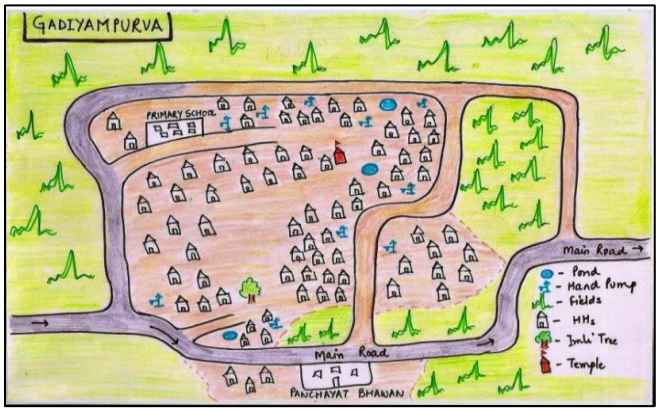


Figure 30: Social and resource map with Gadhyampurva

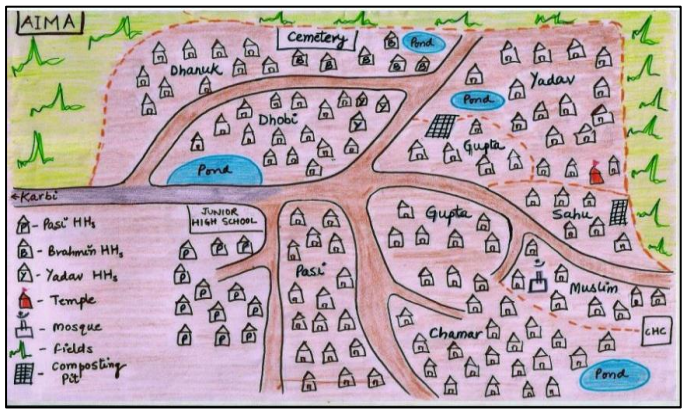


Figure 31: Social and resource map of Aima

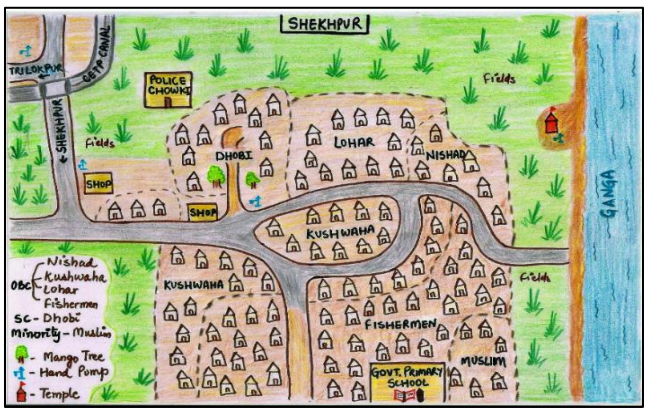


Figure 32: Social and resource map of Sheikhpura

indicating that the villagers rely on groundwater for domestic use. Agriculture was the predominant occupation in these villages. Villagers used diesel and electric pumps to abstract water but also complained of declining water table.

Sheikhpura was well connected to the town and appeared well endowed in terms of natural resources with river Ganga flowing by its side while the CETP Canal water was available on the other side. Agriculture was the main occupation in the village. Agricultural fields were on the outer edge of the village. Irrigation requirements were met through CETP Canal water albeit with awareness of its limitations. The village was inhabited by OBC (*Nishad, Kushwaha, Lohar* and *Machuara*), SC (*Dhobi*) and minority community (Muslim), who lived in clusters. Out of the total population, 295 are males whereas 263 are females with 83 children in the age group of 0-6 years. Out of the total population, 325 were literates with 78% male literacy and 58% female literacy. The village has two schools. Figure 32 illustrates the social and resource map of Sheikhpura

A. Physical infrastructure

i. **Dwelling unit:** Aima GP villages mostly had semi-pucca houses interspersed by few pucca houses of the relatively well-off households belonging to General Caste and OBCs. A few kuccha houses were of lower income group respondents. In Sheikhpura, people lived mostly in *pucca* houses with only a few *semi-pucca* and *kuccha* houses. Here, OBC residents were majority in number owned almost all the agricultural land. They were economically better off than the other groups. **In both the areas, property was inherited and inheritance followed the patrilineal system.**

ii. **Roads:** In both Aima GP villages and Sheikhpura, roads linking the village to the main city were made of *Roller-Compacted Concrete* (RCC). The village roads were unmetalled and mud roads. Connectivity to the main road and urban center was smooth.

iii. **Electricity:** Most households were electrified barring a few that could not afford connection due to low monthly income. But the supply of electricity was erratic and there were frequent power cuts. Gadhyampurva got electrified two years ago, but none of the households had received electricity bill. In Karbigawan, electricity rates were based on metered usage (unit cost). The average expenditure was INR 400 per household. In Aima only a few SC category respondents

had electricity connection. Sheikhpura was fully electrified with minimal power cuts. The electricity charge was based on units consumed. Average monthly expenditure on electricity was INR 450/household (approximately).

iv. **Streetlights:** Hindustan Aeronautics Limited (HAL) adopted village Gadhyampurva for solar-powered streetlights. Karbigawan also had solar-powered streetlights through political efforts. However, Aima did not have streetlights. In Sheikhpura, streetlights were only limited to the area connecting the village to the main road. The Schedule caste and minorities inhabited the ulterior part of the village, which had no streetlights while OBC households were in the lighted parts.

v. **Water source:** Aima GP had two sources of water; namely, hand pump (self-installed and government-installed) and submersible pumps. Both the sources were used for household, livestock and irrigation purposes. Self-installed handpumps and submersible pumps were installed and used by the upper caste *Thakur* and *Brahmin* households. One SC respondent had installed a submersible pump, which was also used by other families of the same caste, free of cost. Villagers perceived change in the quality and supply of drinking water. **They complained of receding groundwater level (receded from 60 ft. to 80 ft. within a span of few years) causing hardness of water which was evident through the pale yellow colored layer that settled upon stored water standing for a few hours**. **The upper caste/high-income group members tried to evade the quality issue by abstracting "sweet" water from 150 to 180 feet but the low-income groups continued to use government installed hand pumps**.

In Sheikhpura, water sources included government and self-installed hand pumps, submersible motors, and piped water connection. While these sources were used for domestic purposes (including livestock), irrigation was mostly done through Common Effluent Treatment Plant (CETP) canal water and very few had installed submersible motors. **Villagers complained of poor water quality despite good groundwater table.** They complained of health conditions like frequent stomach aches, presence of worms in intestine, and degeneration of limbs. Due to such conditions, government had provided the villagers with two types of water sources - blue pipe and motor connection. Both the connections extracted water through the tube well. The former connection had a tube well, installed in a nearby village called Debandi (at 0.5 km). Whereas, the latter connection had a tube well installed near the Sheikhpura Police *chowki*. The former service was free of cost while in the case of the latter, residents had to pay an amount of

INR 180 per month upon use. The SC and the minority category respondents availed water from the blue pipe connection and government installed hand pumps and had issues with the supply as well as quality of water. The blue pipes that were installed had erratic supply of water, while the government installed hand pumps had inferior quality water, with hardness and presence of heavy metals.

vi. **Toilet facility: The villages in Aima GP were open defecation free.** Every household had pour-flush toilets outside the dwelling unit with soak pits of 4 to 4.5 ft. depth. In Sheikhpura, access to toilet facility was directly linked to income level. Higher income groups, generally OBC farmers, had pour-flush toilets within the dwelling unit with soak pits of 3 to 4 ft. depth while the rest, belonging to SC category and non-farmers, practiced open defecation.

vii. **Waste management:** Both Aima GP and Sheikhpura had open drains with poor slope and depth, leading the grey water to ponds (that had filled up) or to the muddy roads in the village. In Aima and Karbigawan, few drains were constructed along with the RCC roads that led the grey water to the ponds. Solid waste management was not practiced and disposal was irregular in both the areas. In Aima GP domestic waste (especially kitchen waste) was either fed to the animals or thrown in/around ponds. Few respondents claimed to compost and prepare manure from the waste. Similarly, in Sheikhpura, household kitchen waste (vegetables, food waste etc.) was disposed irregularly on an empty plot of land. Respondents stated that municipal garbage collection was done only once a month

B. Livelihood and resources

i. **Occupation and income:** In Aima GP, 24 percent of the respondents were involved in non-farm based livelihoods, whereas 76 percent were involved in farming. While agriculture and allied services was the primary source of income for General category respondents, the OBC and SC category respondents practiced subsistence farming and supported their income through labour (in factory or tannery) and other activities. The youth in Aima GP did not show interest in farming due to low profitability and preferred to work in private or government sector in the city. In Gadhyampurva, few farmers were said to have sold land to tannery owners (perceiving the upcoming tannery cluster close to the village-with their displacement from Ganga basin). Sheikhpura had 75 percent farmers and 25 percent non-farmers. The OBC category formed the

main population group. The *Kushwahas* and *Nishads* within OBC community owned maximum land and were primarily farmers. The SC and minority category did not own agricultural land and were primarily employed as laborers. The average annual income from various sources is shown in Figure 33 and 34 for Aima and Sheikhpura respectively. Farming was the most consistent source of income, practiced on large scale by upper caste farmers. Animal husbandry and service were other prominent earning sources but were restricted to a few households. The per day wage rate for workers in informal sector varied from INR 174 to 500 per day, depending on the nature and place of work. Overall, it could be inferred that though few households were now aspiring for jobs in government or private sector or few were engaged in business etc., the preparedness to diversify the livelihood portfolio for risk mitigation was very poor.

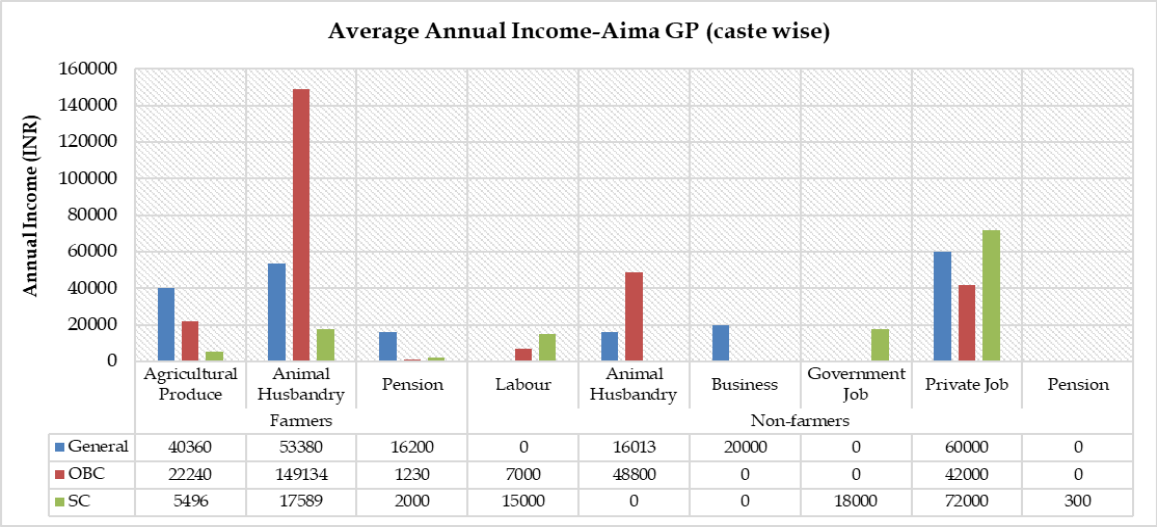


Figure 33: Average annual income of respondents in Aima GP

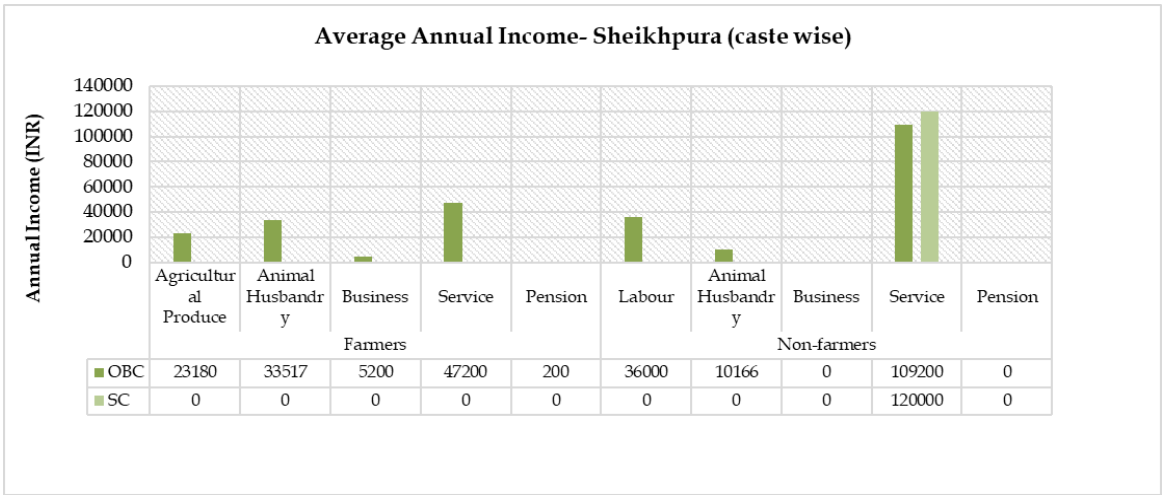


Figure 34: Average annual income of respondents in Sheikhpura

ii. **Livestock holding/ income from livestock:** In Aima GP, the OBC farmers had more livestock holding followed by General category. The OBC households sold milk in much higher quantity and earned higher income through this source than others. The SC category farmers had the least number of units. In Sheikhpura also the OBC respondents had more livestock units and sold more milk than others. The SC farmers had negligible livestock holding and thus procured milk and milk products from market. Table 10 depicts the livestock holding details for farmers in Aima GP, whereas Table 11 shows the livestock details for non-farmers in Aima GP. Table 12 depicts livestock details of Sheikhpura.

Table 10: Livestock details of Farmers in Aima GP

Livestock	No. of household	Total no. of livestock unit	Average water consumption per day per unit (litres)	Average monthly expenditure on fodder per unit (INR)
Cow	12	21	20	1735
Buffalo	20	48	31	4455
Bullock	0	0	0	0
Goat	6	14	6	300

Table 11: Livestock details of non-farmers in Aima GP

Livestock	No. of household	Total no. of livestock unit	Average water consumption per day per unit (litres)	Average monthly expenditure on fodder per unit (INR)
Cow	2	3	17	1334
Buffalo	3	5	18	1740
Bullock	0	0	0	0
Goat	2	12	9	583

Table 12: Livestock details of Sheikhpura

Occupation	Livestock	No. of households	Total no. of livestock unit	Average water consumption per day per unit (litres)	Average monthly expense on fodder per unit (INR)
Farmer	Cow	3	5	18	1600
	Buffalo	4	10	34	1150
	Bullock	0	0	0	0
	Goat	0	0	0	0
Non-	Cow	1	1	20	2000

farmer					
	Buffalo	1	1	40	3500
	Bullock	0	0	0	0
	Goat	2	7	20	395

Livestock was a steady source of income for the households. Villagers in Aima GP sold cow and buffalo milk within the village and to the middleman who sold it in the town. Price of milk varied depending on the quality (fat content) in the milk. Cow's milk was sold to the villagers at INR 25/litre and to the middleman at INR 30/litre. Buffalo milk was sold in the village at INR 30/litre and to the middleman at INR 35-30 /litre. Goat milk was considered nutritious and therefore consumed within the household. Goats were a good cash source, which suffered with the imposition of ban on slaughterhouses in the state. Livestock was fed through agricultural residue or fodder procured at the rate of INR 600/quintal.

iii. **Household assets:** In Aima, General category households were economically better off and thus had better access to modern amenities and durable assets (like tractor, refrigerator, washing machine, inverter etc.). This was followed by the OBC and SC category that commonly owned assets like television, motorcycle, pump set etc. Mobile was common in every household. In Sheikhpura, *Kushwaha* and *Nishad* community that were relatively better off had access to expensive durable assets as compared to other OBC and SC category households. Table 13 shows the caste-based asset holding pattern in Aima GP and Sheikhpura.

Table 13: Caste based availability of assets in Aima GP

Assets/ caste	Radio	Pump set	Motor cycle	Bicycle	Tractor	Car	Mobile	TV	Refrigerator	Washing machine	Inverter
General	1	5	14	11	2	2	25	10	8	4	3
OBC	0	1	5	18	0	0	16	5	1	0	0
SC	0	2	2	13	0	0	20	5	2	0	1

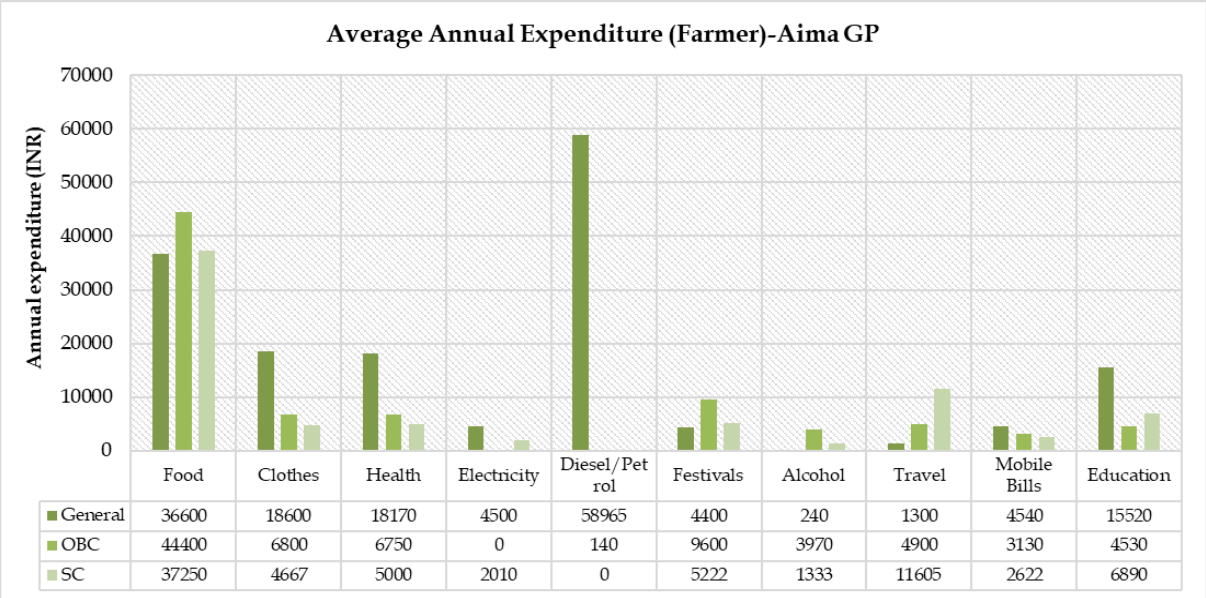
Table 14: Caste based availability of assets in Sheikhpura

Assets/ caste	Radio	Pump set	Motor cycle	Bicycle	Tractor	Car	Mobile	TV	Refrigerator	Washing machine
OBC	0	6	12	12	1	0	29	15	11	1
SC	0	0	1	3	0	0	1	2	2	0

iv. **Fuel type**: While the fuel type included a mix of LPG, fuelwood and dung cakes/biomass; its usage was also linked to the socio-economic status of the households. It was found that the General category households were using a mix of fuelwood, dung cakes/biomass and LPG while the lower income and lower caste households used fuel wood and dung cakes/biomass. The extremely rich households among the General category associated LPG use with status. In Sheikhpura, respondents used mix fuel type.

Wherever fuelwood was used, it was collected from within the village farms or procured at the rate of INR 100 for 100 wood pieces. Households having livestock prepared and used dung cakes while others procured at the rate of INR 100 for 100 dung cakes.

v. **Household expenditure:** As shown in figure 35, maximum expenditure of General category farmers in Aima GP villages was on transportation fuel followed by expenditure on food. In Sheikhpura, OBC households spent maximum on food, followed by transportation expense (see figure 36).



	Food	Clothes	Health	Electricity	Diesel/Petrol	Festivals	Alcohol	Travel	Mobile Bills	Education
General	36600	18600	18170	4500	58965	4400	240	1300	4540	15520
OBC	44400	6800	6750	0	140	9600	3970	4900	3130	4530
SC	37250	4667	5000	2010	0	5222	1333	11605	2622	6890

Figure 35: Average annual expenditure of farmers in Aima GP

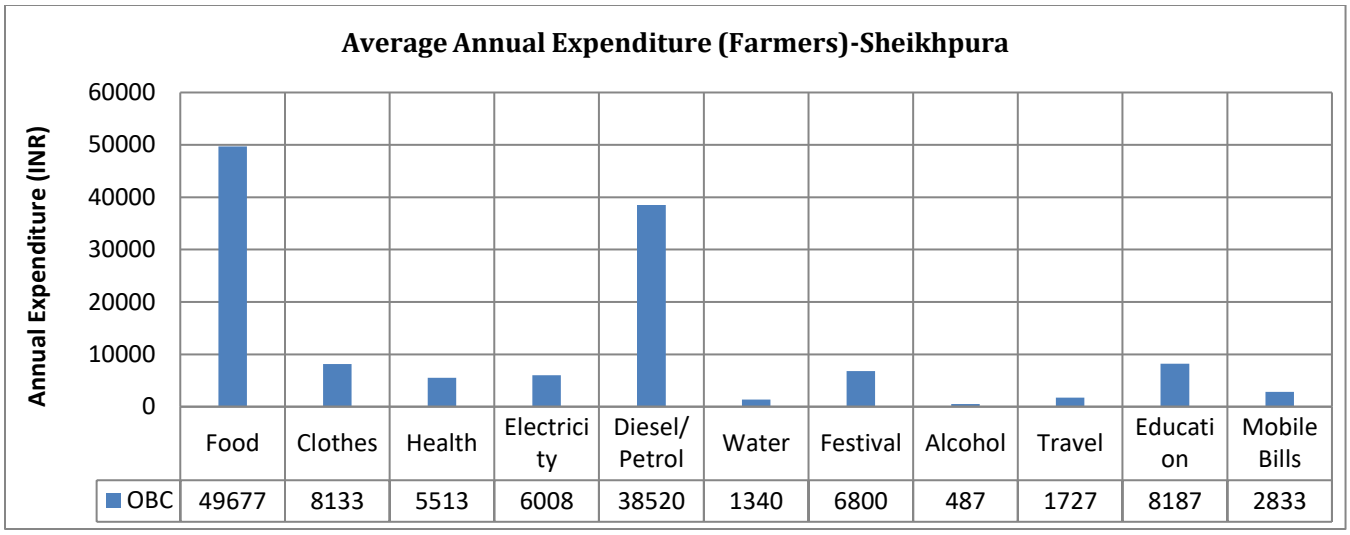


Figure 36: Average Annual Expenditure (Farmers)-Sheikhpura

Non-farmers in Aima GP (primarily among OBC and SC categories) and Sheikhpura (primarily lower income OBC and SC categories) also spent maximum amount on food items. Expenditure on festivals and health items followed food expenditure in Sheikhpura and Aima GP respectively. The expenditure pattern on education showed the lackluster attitude.

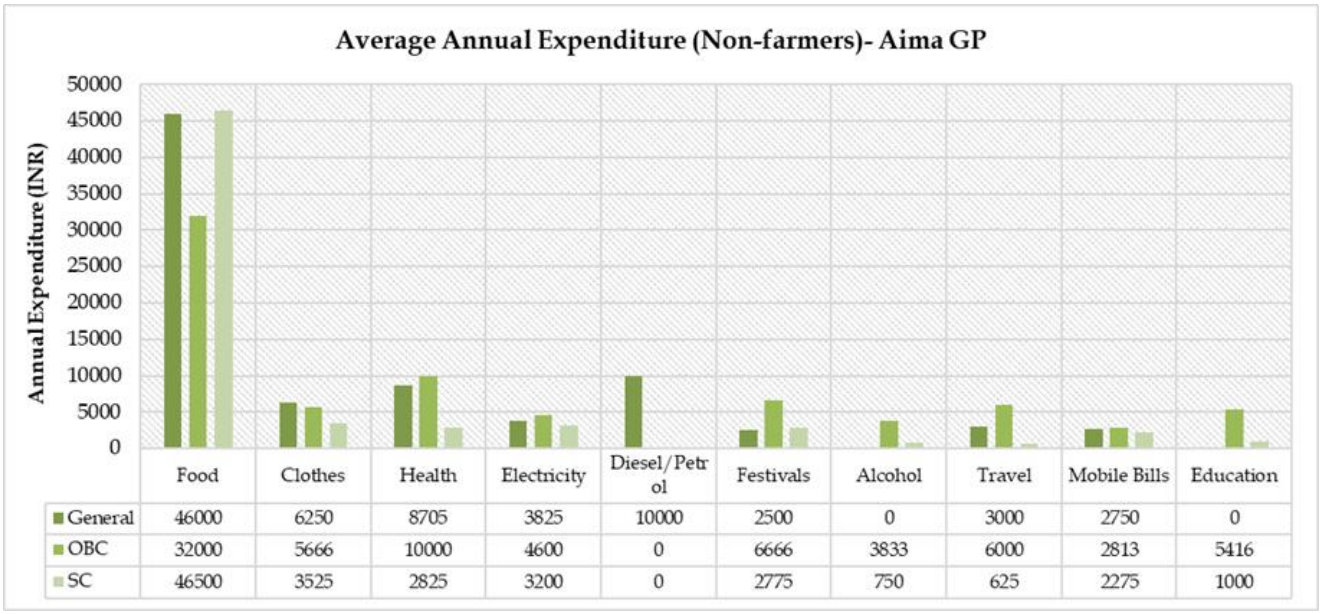


Figure 37: Average Annual Expenditure (Non-farmers)- Aima GP

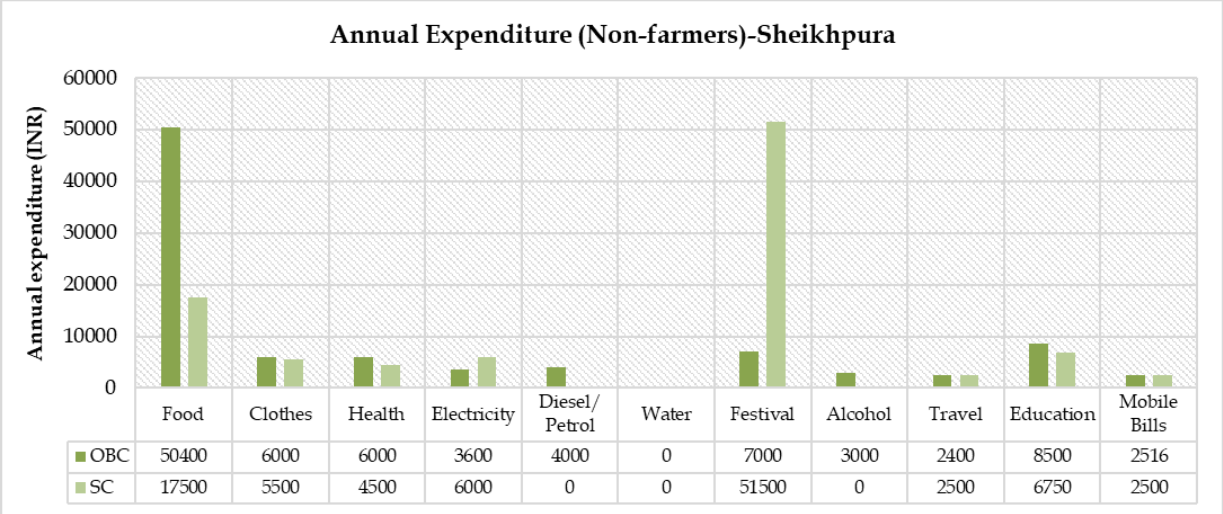


Figure 38: Average Annual Expenditure (Non-farmers)- Sheikhpura

Expenditure on alcohol was a concern among the migrating and upwardly aspiring OBC category. Figure 37 and 38 show the expenditure pattern among the non-farmer groups in Sheikhpura and Aima GP respectively.

vi. **Savings**: Almost every household in the study villages had bank accounts. Male heads of the household were single account holders barring few cases of joint account holding with spouse. Most of the OBC category respondents in Sheikhpura and the General category respondents in Aima GP saved in banks on monthly basis. The SC category respondents deposited money on quarterly basis in the bank. However, most of them did not save enough to deposit/invest. None of the respondents shared any detail about savings and investment in shares/mutual fund/property etc.

vii. **Land holding pattern**: The General category households in Aima GP had larger land holdings as compared to OBC and SC households. The average size of landholding of respondents belonging to the General caste was 7.05 *bigha*, while OBC households had an average landholding of 3.24 *bigha* and SC households had 1.42 *bigha*. The OBC households owned most or all the agricultural land holding in Sheikhpura.

viii. **Cropping pattern**: The major crops grown in the villages were wheat (varieties 343, 337 and 1180), *jowar* (varieties mentioned locally as *karbi* and *jundi*), *berseem* (desi), *lahi* (varieties mentioned as *krishna* and *kranti*) and roses. Choice of crop was decided based on water requirement and yield. Rose was cultivated as cash crop in Sheikhpura due to its proximity to the

town and access to lucrative market. Crops cultivated in the two villages were almost similar (except flower production) and depicted in the figure 39.

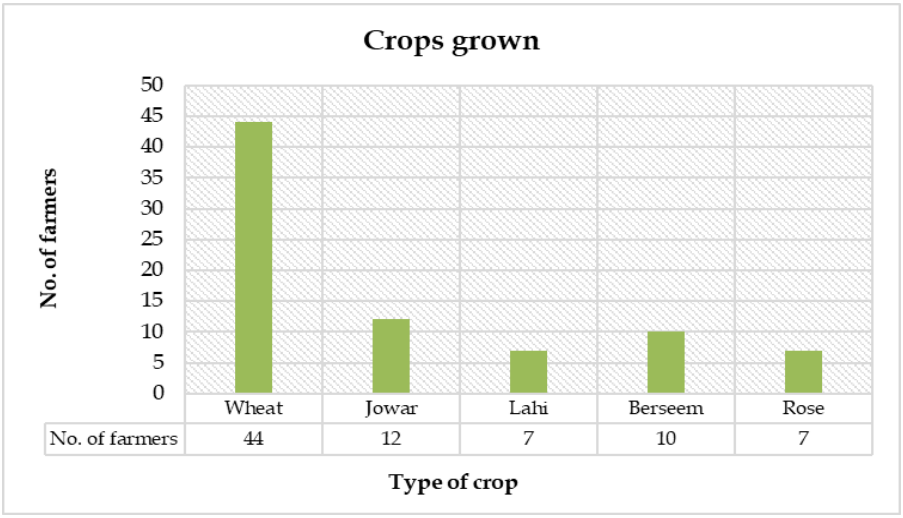


Figure 39: Crops grown in Kanpur

ix. **Crop productivity:** The total cost of cultivating wheat in one *bigha* land was about INR 1875. For j*owar*, l*ahi*, *berseem* and Rose this was stated as INR 605, 1640, 3000 and 1000 respectively. The cost of cultivation included cost of seed, fertilizer and pesticide. The main fertilizers used were DAP, urea, sulphur and zinc. The preferred pesticide was Coragen. Cost of labour varied based on nature of work and availability of labour. The standard cost of labour was within the range of INR 150 to 300/day, depending on the activity. Figure 40 shows the cost and revenue for each of the crops that were cultivated in the two villages. Table 15 shows break-up of the yield and revenue for each crop that was grown.

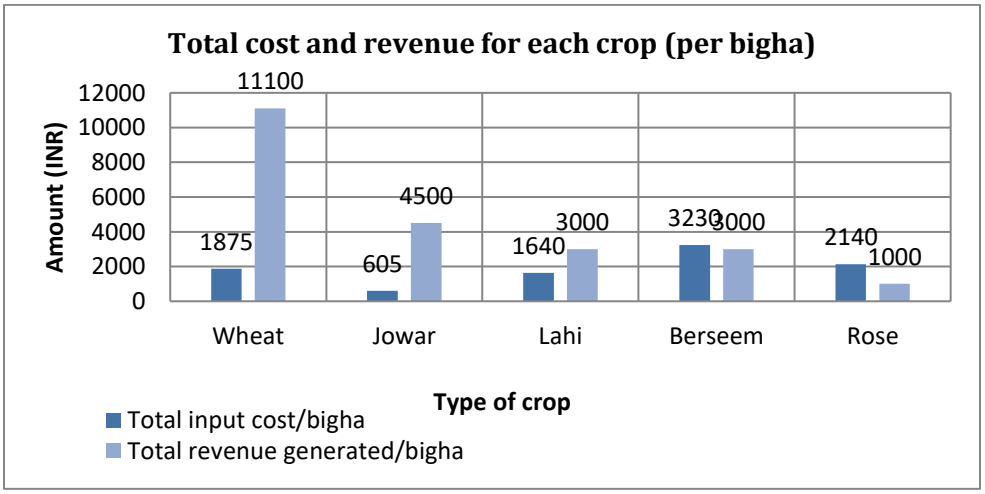


Figure 40: Seed costs, yield and revenue for each crop

Table 15: Total cost and revenue for each crop (per bigha)

Crop variety	Quantity of seed per bigha (kg)	Cost of seed	Total input cost (INR)	Average yield per bigha (quintal)	Selling price per quintal (INR)
Wheat	25	30	1875	8 to 9	1200 to 1400
Jowar	2 or 8*	40	605	3 to 4	1200 or 4000 to 5000*
Lahi	1	80	1640	5	3000
Berseem	8	1440	3230	12	1000
Rose	20	800	2140	0.05	50/Kg (October) 10/Kg (Other seasons)
***Depending on seed variety**					

x. **Irrigation**: In Sheikhpura, farmers relied on CETP canal water for irrigation. However, in Aima GP, farmers relied mainly on groundwater abstracted through electric pumps. Irrigation source (thus water quality) had direct impact on the use of fertilizers and pesticides for farming. Farmers in Sheikhpura stated high use of pesticides but low use of fertilizers, due to the presence of heavy metals in water that gave "a lot of power". Canal water was hardly used for irrigation in Aima GP. Here the incidence of pest attack was lower, but farmers admitted high fertilizer use (unlike Sheikhpura). Cost of irrigation was negligible in Sheikhpura as the farmers only had to construct mud banks to redirect water from the canal to the fields. Some of the fields were also adjoining the canal. In Aima GP, irrigation formed a substantive portion of the expenditure. The cost of electricity for one hour was INR 100. Where the farmers borrowed or leased electric pump, the rent was about INR 100-150 per hour of usage.

xi. **Marketing of agricultural produce**: Some of the farmers sold their produce directly in the market while others sold it through middlemen. In absence of infrastructure for storage, farmers spent considerably on transportation of produce. They complained of considerable risk of damage and low bargaining power in absence of infrastructure. The nearest market/mandi for Aima GP was *Ruma*, while farmers in Sheikhpura sold their produce in *Ramadevi*. Flowers were sold in Trilokpur (2 km) and Shivala Mandi (4 km).

C. Social and institutional infrastructure

i. **Education:** Most of the farmers in the study villages were educated either till primary or secondary school. Very few were encouraged to study beyond secondary level as they either lost interest or were engaged in farming and other household chores. Figure 41 shows the level of education among the farmers and figure 45 shows the education level for non-farmers in the two study villages. The graph shows maximum respondents from the OBC category since Sheikhpura primarily had OBC farmers.

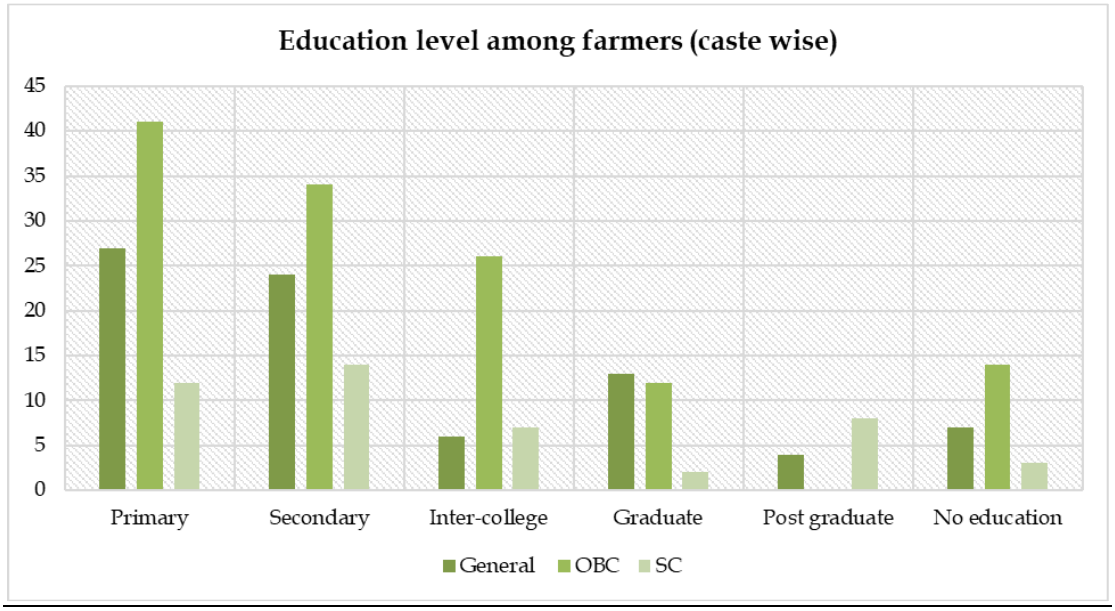


Figure 41: Education level among farmers (caste-wise) in Kanpur

Among the non-farmers, most of the respondents were either uneducated or educated till the primary or secondary levels. Very few received higher education while none was a post-graduate.

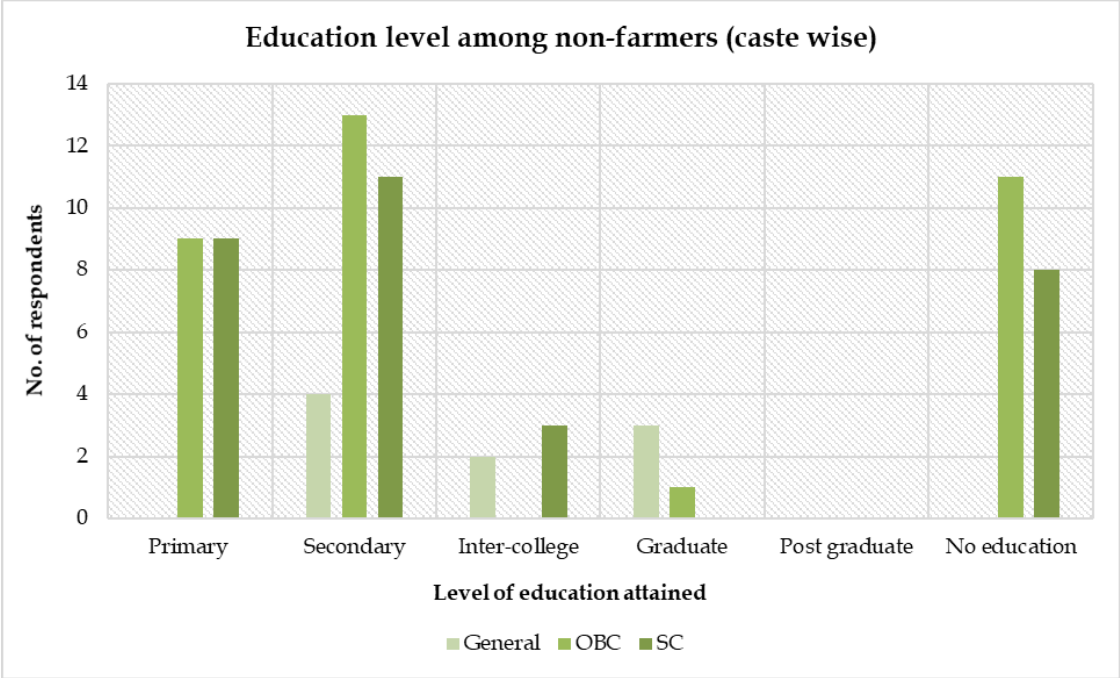


Figure 42: Education level among non-farmers (caste wise) in Kanpur

Women respondents were either uneducated or had completed primary or secondary levels of education. Figure 43 shows the trend of female education (caste-wise).

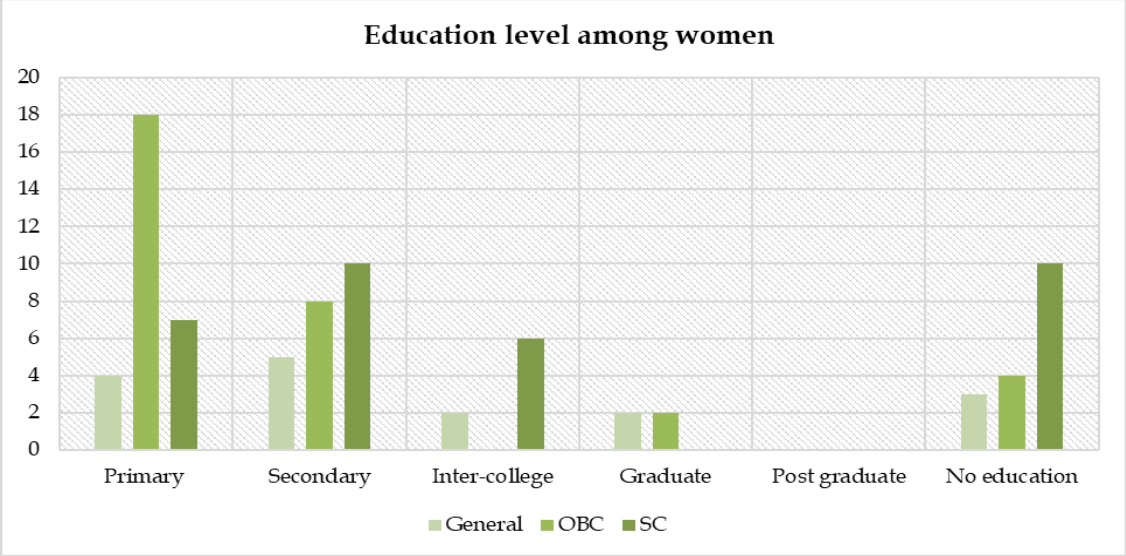


Figure 43: Education level among women (caste-wise) in Kanpur

ii. **Health:** Few respondents suffered from chronic diseases/ailments like arthritis, tuberculosis, diabetes, filaria, anemia, joint pain, blood pressure irregularities and fistula. Other common

ailments included diarrhea, fever, hepatitis, intestinal worm, kidney stone, chicken pox and typhoid. Respondents preferred private facilities to public, owing to better infrastructure, adequately equipped hospitals/clinics, greater number of healthcare professionals and better care. However, private hospitals were less affordable and thus, respondents could not avail adequate healthcare facilities always. Sometimes, local chemists and pharmacists (colloquially known as '*Jhola-chaaps*') were resorted to. In Aima GP, ASHA and *Anganwadi* center took care of the healthcare and medical needs of children and pregnant women. The staff of these institutions provided dietary and nutritional advice. They also acted as a crucial link between the members under their care and the government hospitals.

Health was also affected due to inadequate sanitation facilities for all. This particularly affected women. During menstruation, most of the women used cloth, as they could not afford sanitary napkins. These clothes were then buried or burnt. As mentioned earlier, waste management and water quality were already cited as problems.

iii. **Banks, credit facilities and Self-Help Groups (SHGs)**: Banks were in towns or cities but were accessible by all the respondents that had bank account. Most of the male respondents had account in private bank. Many of the female respondents were joint account holders with their husband, though they had little access to the bank or to the money/benefits thereof. Banks were preferred over other institutional sources like middlemen for credit purposes. Most of the farmers had Kisan Credit Cards, which they used to borrow money 7% rate of interest for agriculture purposes. Social networks were relied upon for all other purposes.

Aima GP had a SHG where the women regularly deposited money, however, the members did not seem to be well informed about the activities and benefits. This was coordinated by some external organization. Members could avail loan from the SHG for agriculture or personal reasons.

D. Governance structure, participation and conflict resolution

i. **Governance structure**: *Pradhan* was the head of the villages in Aima GP. The position of the Pradhan was reserved for various categories in each tenure (based on caste and gender i.e., SC female, OBC male, general category female etc.). During the study period, a woman Sarpanch from OBC category headed the Panchayat (from village Gadhyampurva). Though she was well

informed of the village affairs, most functions of the office were handled by the male family members.

On the other hand, Sheikhpura came under the jurisdiction of Kanpur Nagar Nigam. Thus, there was no elected representative of the village. Villagers perceived the administration as very far from them and were left bereft of many government programmes and benefits that were extended to the rural areas.

ii. **Participation in decision-making:** In Aima, people did not seem very happy with the functioning of the Panchayat. Meetings were irregular and mostly marked change in tenure or introduction of new government scheme. An apparent disinterest was perceived with contradicting opinions of the *Pradhan* and the members. While the *Pradhan* claimed to make regular and extensive announcements to ensure participation of villagers in meetings, people said they either did not receive the information or were not interested. Many respondents felt that meetings often took place between the Pradhan and a few selected people "in secret". Women were often not invited to such meetings as it was "a man's business". Their interest was solicited only during elections. The non-participation of women was evident from their absence from other institutions also.

iii. **Conflict Resolution:** In case of any conflict arising within the community, irrespective of the village being studied, the respondents preferred approaching the nearest police station or even filing a case in the court of law. The counsel of the *Pradhan*, in case of Aima GP, was hardly ever sought.

E. Gender dynamics and gender-resource interactions

i. **Gender roles and responsibilities**: Women were mainly responsible for tasks like cooking, cleaning, fetching water, taking care of animals and other domestic chores. They could voice their opinions in matters like savings and expenditures. However, in most matters like family planning, education, marriage, financial planning and crop choice, women were not able to take decisions. All agricultural related tasks, market transactions, decisions pertaining to farming and decisions pertaining to property were in the realm of the male members. In some cases, male members helped in household chores like fetching water.

ii. **Gender-resource interactions**: By their responsibilities, women came closest to the natural resources, but their role in managing natural resources was limited. They had no access to

property; they were "missing" from institutions; and lacked a "voice" even after affirmative steps through reservation.

iii. **Women's representation and participation in institutions:** The study in Aima GP found that despite a woman Sarpanch, the presence of women in institutions was rare. This was an extension of gender norms that were fixed at household and community level. As a result, women themselves had started perceiving their insignificance in institutional matters, often labeling it as "a man's business". In absence of sufficient numbers, even those women who were interested in attending meetings were unable to participate. The study could not see active involvement of women in community level decisions. Their presence only assumed significance during elections. Women were also not part of any community level groups or '*mahila gats*' and remained passive members of the community.

However, women in Sheikhpura were relatively more exposed to town and its facilities. Yet they were not allowed to travel to these places alone, irrespective of their age. They could only visit the market and other town facilities in the company of a male family member. Such discrimination manifested in their educational and economic status also.

3.5 Conclusions

The study findings from Hardoi and Lakhimpur showed that the villages are marked by poor physical infrastructure in terms of electrification, sanitation and waste management facilities, connectivity to towns and access to market infrastructure. The general caste farmers were economically better off than the OBC and SC farmers with larger land holdings (and other assets), better access to resources and higher earnings. The average annual income from farming was approximately INR 1,67,769, subject to the land holding of the farmer. Total revenue for wheat and sugarcane per acre was INR 17,500 and INR 94,500 respectively. However, farmers preferred to grow a combination of wheat and sugarcane for reasons of food security. The villages were marked by absence of drinking water supply and irrigation facility, thus creating pressure on ground water. This trend will increase in future with more farmers willing to switch to sugarcane cultivation due to high productivity and assured market. There was also an indication of affluent farmers' possibility of higher benefits due to excessive cost of irrigation infrastructure (though electricity was subsidized in current political scenario). Livestock holding was more like a risk measure and did not make a

regular source of income. Savings was not a common habit, worse still amongst the SC households. Almost 60 percent of the farmers availed loans for productive purposes but only a mere 19 percent had crop insurance. Overall, most of the income was from farming but highly subject to risk and lack of access to institutional credit, market institutions, storage infrastructure and a resultant low bargaining power.

In terms of social infrastructure, the villages suffered from poor education infrastructure and literacy status, poor access to health institutions and poor health services, low social capital, absence of institutions and high caste discrimination. Caste dynamics was strongly reflected in the socio-economic interactions and the status of the households. The study found that the SC community was most vulnerable, particularly where there was a mix group. The villages had no functional institutions and therefore low levels of awareness and social capital. Panchayat was not strong and therefore police was resorted to solve even minor conflicts in the village.

From a gender lens, strong discrimination was found in women's access to social, economic and political institutions. There was strong gender stereotyping where women were restricted to reproductive roles and men associated with productive roles. Concepts of women's access to space and freedom of choice were alien. Most of the women were uneducated and faced restricted participation in workforce and market institutions. There was no tenurial security and inheritance followed patrilineal systems. Decisions pertaining to education of children, household expenditure, marriage and family planning were taken jointly by male and female members of the households. However, women did not have any say in decisions pertaining to resources, like property, crop choices, savings and investment. While women found very little space in decision making role at the household level, the representation and participation in village governance was dismal. Only one village had a woman Sarpanch. However, the functional office was held by her husband. Participation was lowest among the SC households, who also faced severe caste discrimination.

Findings from Kanpur showed that the villages were better endowed in terms of physical infrastructure (land holding, houses, energy access and connectivity to towns) but highly differentiated in terms of caste dynamics. Access to social infrastructure (education, health, mobility) was better in Kanpur, however, incidence of disease was common. This included chronic diseases like arthritis, tuberculosis, diabetes, filaria, anemia, joint pain and other common ailments like diarrhea, fever, hepatitis, intestinal worm, kidney stone, chicken pox and typhoid. Respondents preferred private facilities to public, owing to better quality services. Groundwater was the common source for drinking and irrigation in Aima as compared to Sheikhpura that had access to piped water

for drinking and CETP canal water for irrigation. This was perceived to cause problems such as skin rashes and degeneration of limbs. Economically, the General and OBC category respondents were better off in terms of occupational diversity, land holding size, asset ownership and livestock holding. Agriculture was the primary occupation for General category farmers while OBC and SC categories practiced subsistence farming and supported their income through labour and other activities. The major crops grown in the villages were wheat, jowar, *barsheen* and roses. Farmers in Sheikhpura specified high use of pesticides but low use of fertilizers, attributing it to the presence of heavy metals in water that gave "a lot of power". Access to storage infrastructure and market was poor. Thus, farmers had very low bargaining power. The youth did not show interest in farming due to low profitability and preferred to work in private or government sector. In Aima, a few farmers were said to have sold land to tannery owners (perceiving the upcoming tannery cluster close to the village). Livestock provided a steady source of income but there was no organized market for sale of milk. Although, all the respondents had bank account, savings habit was again not very common. Farmers had access to banks and used Kisan Credit Cards to borrow money for agriculture purposes. Institutionally, the villages did not seem very robust in ensuring access to good infrastructure or accountability mechanisms (though the Aima Sarpanch took lot of credit in construction of toilets).

Gender roles were restricted to associating reproductive role with women and productive role with men. Women were mainly responsible for tasks like cooking, cleaning, fetching water, taking care of animals and other domestic chores. They could voice their opinions in matters like savings and expenditures. However, in most matters like family planning, education, marriage, financial planning and crop choice, women were not able to take decisions. All agricultural related tasks, market transactions, decisions pertaining to farming and decisions pertaining to property were in the realm of the male members. By their responsibilities, women came closest to the natural resources, but their role in managing natural resources was limited. They had no access to property; they were "missing" from institutions; and lacked a "voice" even after affirmative steps through reservation. Despite a woman Sarpanch in one village, presence of women in institutions was rare. This was an extension of gender norms that were fixed at household and community level. As a result, women themselves had started perceiving their insignificance in institutional matters, often labeling it as "a man's business". In absence of sufficient numbers, even those women who were interested in attending meetings were unable to participate. The study could not see active involvement of women in community level decisions. Their presence only assumed significance during elections. Women in Sheikhpura were relatively more exposed, yet their mobility and decision spheres were

limited. They could only visit the market and other town facilities in the company of a male family member. Such discrimination manifested in their educational and economic status.

Chapter 4
SOIL – WATER – CROP LINKAGES

4.1 Understanding the 'soil – water – crop' inter linkages

It is well known that different agro-ecological zones have diverse types of soil and nutrients. They are also climatologically different and support different vegetation and crops. It is essential to select the right crop for the area, to optimize the crop yield and crop water requirements. To understand the soil water crop linkages, soil and water analysis and crops grown were studied.

The figure 44 explains the process.

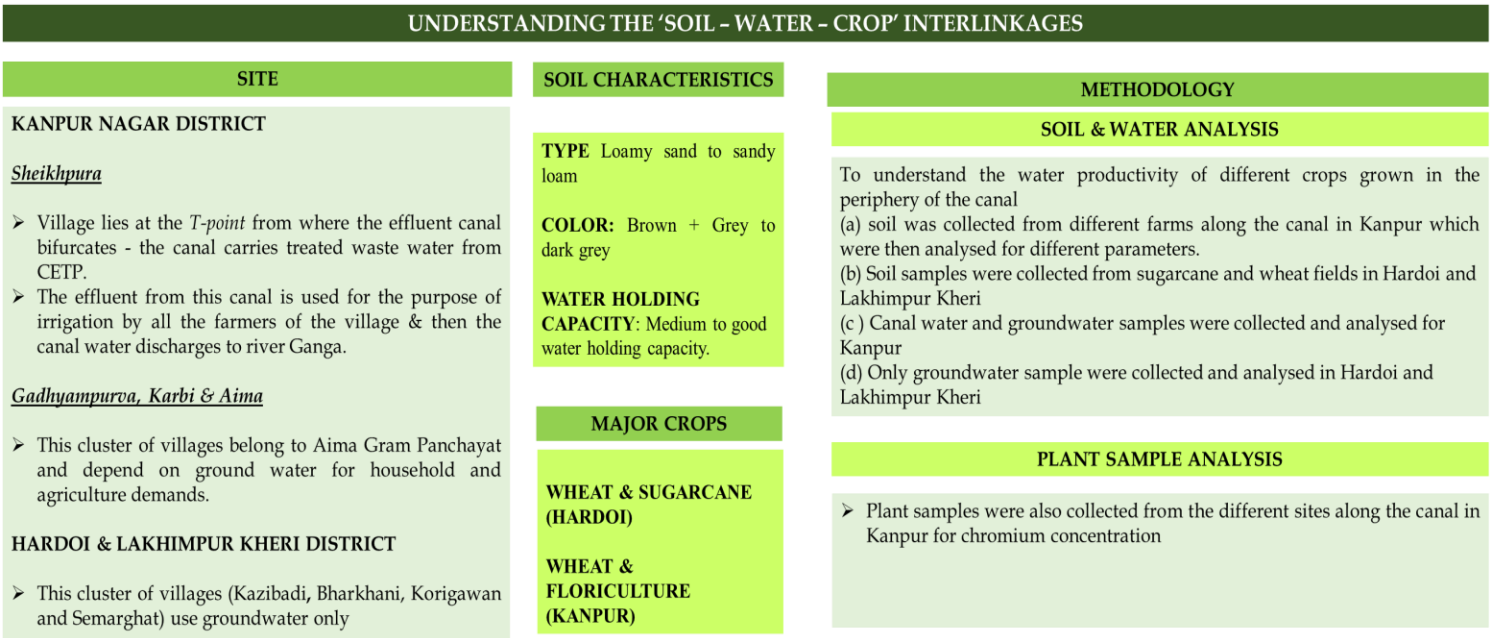


Figure 44: Understanding the soil-water-crop interlinkages

4.2 Kanpur: Soil analysis and plant analysis downstream of the CETP

The observations for soil analysis are as given in the table below:

Sample/ Parameter	Site-1	Site-2	Site-3	Site-4	Site-5	Sludge
Chromium Concentration(µg/g)	52.940±3.35	24.446±5.17	81.5122±0.93	18.153±1.40	33.086±1.13	121.762±11.85
Calcium Concentration(µg/g)	2632.67±129.31	2395.00±70.43	3140.93±165.05	3048.0±83.72	651.00±73.26	4407.87±74.26
Sodium Concentration(µg/g)	847.73±45.84	910.13±162.48	1025.33±48.43	1378.8±20.36	690.67±31.25	1344.13±17.26
Phosphate Concentration(mg/L)	1.207±0.03	1.623±0.10	1.460± 0.10	1.090±0.08	1.437±0.06	3.620± 0.03
Chloride Concentration (mg/L)	40.0	72.0	49.3± 2.31	90.6± 2.31	49.3± 2.31	66.6± 2.31
Sulphate Concentration (mg/L)	8119.8±71.55	8806.4±681.11	8497.8± 628.01	10167.1± 118.02	8195.4±109.11	8516.6± 76.38

The soil samples were tested for chromium, calcium, sodium, phosphate, chloride and sulphate because all the sites were downstream of the tannery and the CETP. The field sites are adjacent to the canal carrying CETP effluent. These chemicals are specifically used in various tannery operations and thus find their way in the effluent canal. Except phosphate which has low concentration (which is a fertilizer and our discussion with farmers has shown that pesticides are used and not fertilizers).

The observations for plant sample analysis are as given in the table below:

S. No	Site	Sample	Part	Chromium Concentration(µg/g)
1.	Just from the side canal unaligned border	P-1	Shoot	2078.491±135.07
2.	Adjacent farm of canal	P-2	Shoot	65.975±11.16
3.	From the mid end farm near canal	P-3	Shoot	33.119±9.47
4.	From the mid end farm near canal	P-3	Root	40.689±1.87

For plants, only chromium concentration was determined as absorption of chromium by plants may result in the heavy metal being added to the food chain. The results show that plants adjacent to the canal have high chromium content, while those even 50m away from the canal do not show high content (though it is above the threshold limit, it is the total chromium content hence not the most harmful). Cultivation of inedible crops including likes flowers is recommended.

SOIL ANALYSIS – INFERENCE	PLANT ANALYSIS – INFERENCE
➢ High concentration of chromium is observed in soil samples taken from farms close to the canal. ➢ High level of calcium and sodium is directly responsible for introducing alkalinity in the soil. ➢ Chloride concentration at various sites indicates towards the saline nature of soil, adjacent to the canal.	➢ Presences of chromium could be seen in all the plant samples. ➢ Semi-submerged plant has high chromium content.
Note: Standard permissible concentration of the parameters tested above are needed for soils, as currently only specific case studies are cited for such parameters.	As we move away from the canal, chromium concentration decreases in plants.

4.3 Canal mapping

For this study, the canal carrying treated effluent from CETP is termed as the *effluent canal*. Earlier, sewage water was mixed with water from the river Ganga and provided for agriculture. It was after the commissioning of the CETP in the 1990s at *Jajmau*, downstream of the cluster of tanneries; the treated tannery effluent is diluted with domestic sewage, and then released through this canal.

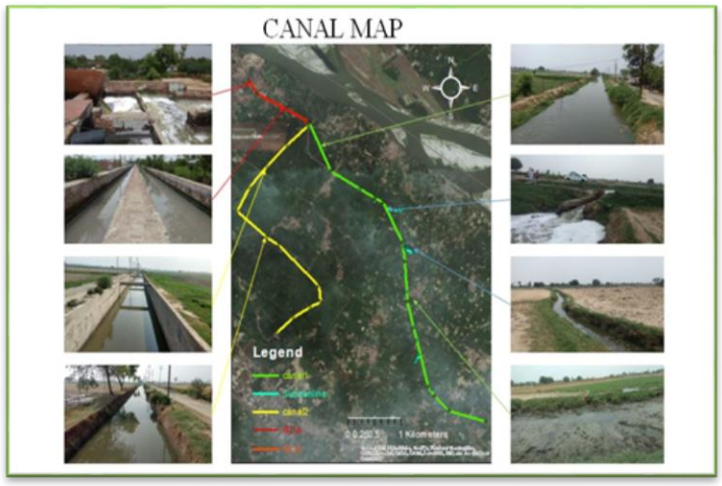


Figure 45: Canal map

A. Mapping methodology

For the convenience of this study, the entire canal has been divided into three parts. Figure 46 is a line diagram of the canal and presents the colour coded divisions of the entire canal

- ***Red stretch 1:*** The stretch that starts from CETP outlet to Sheikhpura village has been termed as **main canal**.
- ***Green stretch 2:*** This stretch represents **canal one**.
- **Yellow stretch 3*:*** This stretch represents **canal two**.

During the study, GPS coordinates along the canal were collected to systematically map the canal using ArcGIS platform.

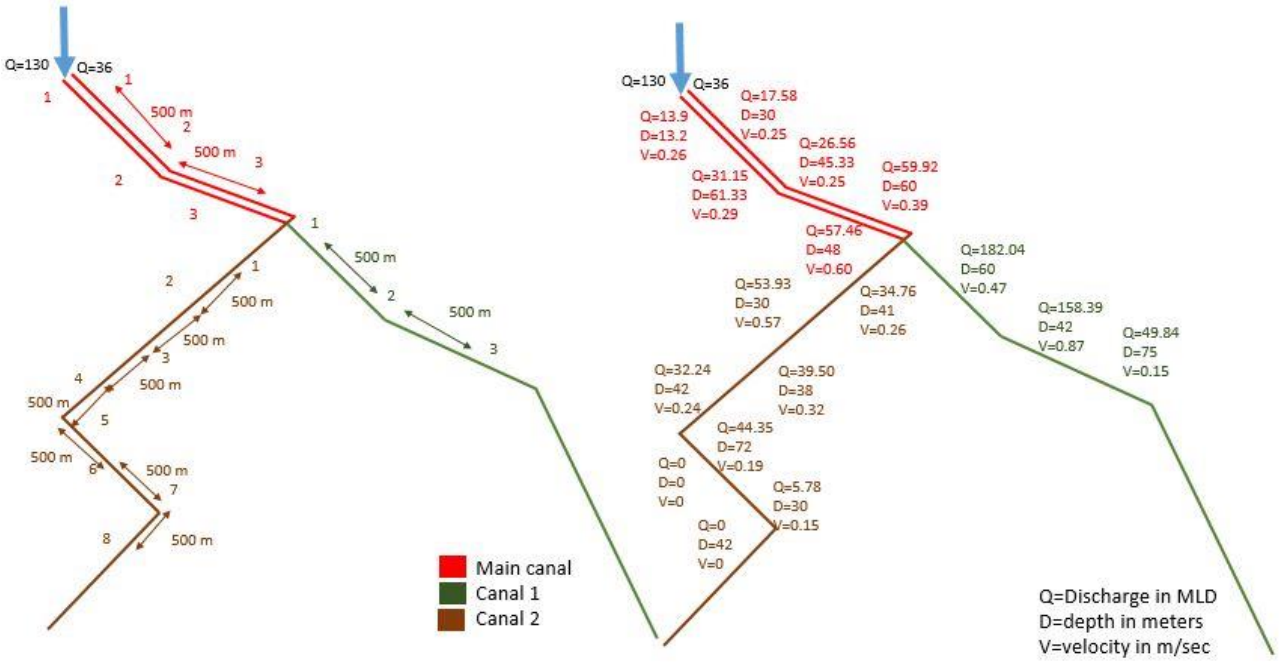


Figure 46: Line diagram showing discharge values at various points along the canal

B. Analysis and inferences

The discharge calculations for the various sections of the canal have been included in Annexure A. The line diagram as shown in Figure 46 depicts the various sections and sub-sections of the canal, with their respective discharge data. A total of 130 MLD of treated effluent along with 27 MLD of domestic sewage is released by the CETP into the waste water canal through pipelines. The velocity of flow and discharge of water into the canals is varied and is dependent on the quantity of effluent released from the CETP drains.

It is important to note that waste water is utilized by farmers for irrigation. The main canal is entirely cemented. The discharge through this canal is high always. Near Sheikhpura, the main canal bifurcates into two canals.

Figure 47: Main effluent canal and outlet - downstream of CETP

- **Canal one** flows towards Trilokpur and Aima village. This stretch is unlined and the flow reduces as the distance increases from the CETP.
- **Canal two** is lined, the flow of water reduces with an increase in distance from the junction point.

Both canals are used for irrigation. Water is allowed to flow from one of the sections of unlined stretch of canal one to irrigate the fields. From the lined stretch of canal two, water is pumped to the fields. Excessive water use has resulted in the drying up of both canal dries up after a certain distance.

4.4 Ground water mapping

The nature of ground water was also studied at the four village sites of Sheikhpura, Gadhyampurva, Karbi and Aima. Major sources of ground water extraction were identified such as handpumps, borewells, wells and ponds.

- Using GPS, coordinates of these ground water extraction sources were captured and mapped through the ArcGIS platform. environment to identify their location throughout the villages.
- During the study, the usage of water was estimated based on information gathered through informal interviews with users and observing the mechanism for collection and storage of water.
- Furthermore, two samples of ground water were collected from all four villages. These eight samples were tested in TERI SAS laboratory, against certain drinking water parameters; i.e., pH, conductivity, total alkalinity, hardness, chloride, total iron, nitrate, sulphate and fluoride. For the village of Sheikhpura, water was tested for chromium as well.

Village wise ground water mapping

A. ***Sheikhpura***

Village Sheikhpura is situated on the banks of the river Ganga. The village is an integral part of the

Figure 48a: View of broken section to allow extraction of water from Canal One

Figure 48b: View of the cemented main canal

Kanpur Nagar Nigam and thus has access to piped water supply from Kanpur Jal Nigam.

Table 15: Sheikhpura ground water mapping

SHEIKHPURA GROUND WATER		
Sources	**Number**	**Depth**
Handpump	30-40	35-41 m
Borewell	5	39-45 m
Well	4-5	30-45 m
Ponds	-	-

- This access to piped water is a recent phenomenon, however handpumps have been installed throughout the village.
- ***Hand pumps: Each handpump is shared by a cluster of four to five households***. The water from the hand pumps are primarily used for domestic consumption, cooking, washing, bathing and providing drinking water and food to the cattle and livestock.
- ***Borewells:*** It is important to note that borewells have also been installed in few houses and water from these borewells are extracted through pumps ranging from 6 hp to 10 hp.
- Since the supply of piped water is intermittent, the water from the **hand pumps are extensively used by villagers and is the main source of water supply.**
- ***Dug wells:*** During the site visits, it was observed that four to five **the dug wells** were left abandoned. Two of these wells had been reduced to sites where garbage was being dumped. There are no major **ponds** within the village boundary.
- ***Unlined channels:*** Some **unlined channels** were seen leading from houses that carried sewage. These sewage lines mix with agriculture return flow from fields at various places and flows to river Ganga.

B. Gadhyampurva

Village Gadhyampurva depends primarily on ground water for both irrigation and household consumption, including water use for cattle and livestock. Water is extracted through handpumps and borewells.

- ***Hand pumps:*** Each handpumps is shared between four to five households. Apart from domestic consumption, cooking and washing, this water is used for bathing and providing drinking water and food to cattle.
- ***Borewell***: Few borewells have been privately installed in a small number of households. Water from borewell is extracted through pumps of 6 hp to 10 hp.

- ***Dug wells***: There are three dug wells in the village, out of which two are dried up and abandoned. The third well collects water during rains which is then pumped out for irrigation.
- ***Natural ponds:*** Out of the two ponds in the village, one has dried up. **The sewage of households is collected in the larger pond which is about 25 m in length and 12 m deep**. It is in this pond that the sewage collects from households of the village collects. It was observed that the pond was eutrophicated due to sewage flow. It overflows during monsoon. **This pond can provide to be an ideal site for collection and storage of rainwater, once cleaned.**
- This village uses canal water too for irrigation.

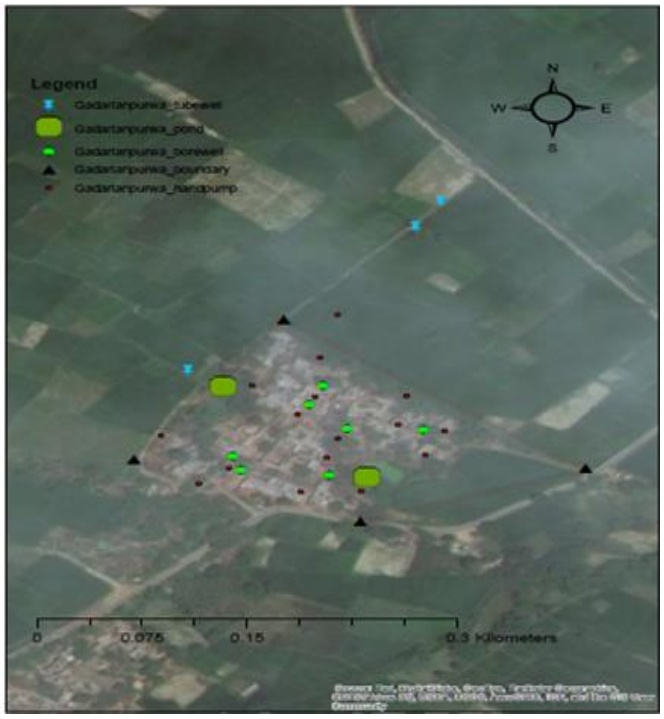


Figure 49: Gadhyampurva location image

Table 16: Gadhyampurva ground water mapping

GADHYAMPURVA GROUND WATER		
Sources	**Number**	**Depth**
Handpump	20-25	36m
Borewell	6-7	55m
Well	3	46m-91m
Ponds	2	4.5-6 m, 9-12m

C. ***Aima***

Village Aima is the largest amongst all the four villages.

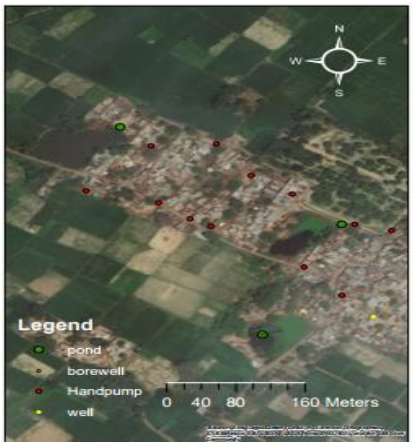


Figure 50: Aima location image

- ***Hand pumps:*** Aima has 70-75 handpumps that goes to a depth of 41m. There are about 30 borewells that goes upto 55m depth. Water is used for household consumption like cooking, drinking, bathing and for livestock.
- ***Dug wells*****:** There are four dried up dug wells. These wells have a depth of about 37 m. They have been abandoned.
- ***Natural ponds*****:** Aima has 3 ponds. These ponds have the following characteristics and usage:
  - One of the ponds is 40m in length, 20m in breadth and 3m depth.
  - It is used to collect sewage from the village.
  - The other two ponds are used for bathing cattle. Among these, one of the ponds measuring 70m in length, 30m in width and 10m in depth had low water levels during the month June.
  - The larger pond of 75m in length, 50m in breadth and 7m in depth had sufficient water during the study period

D. ***Karbi***

It has about 26-28 handpumps, the number of borewells is very less in this village. Apart from domestic consumption, cooking and washing, this water is used for bathing and providing drinking water and food to cattle. Water from borewell is extracted through pumps of 6.7 hp to 10 hp. There are four dried up dug wells that has a depth of about 33m -34m, they are abandoned at present.

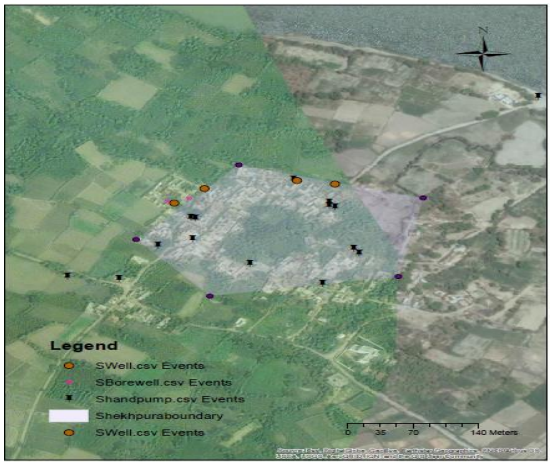


Figure 51: Karbi location image

Among the four study sites, the village of Karbi has the largest number of ponds. There are 6 ponds in total.

There are 3 ponds where sewage from households collects. These ponds were seen to be eutrophicated. These ponds have nearly similar dimensions i.e. 20 m length, 25m width and 3 m depth. Two ponds are used for bathing cattle by villagers. They are 25m in length, 15m in width and 3 m in depth. These were found to be filled with water. The sixth pond had dried up.

Table 18: Karbi ground water mapping

KARBI GROUND WATER		
Sources	**Number**	**Depth**
Handpump	26-28	36m
Borewell	3	55m
Well	4	34m
Ponds	6	25m*15m * 3m

4.5 Water productivity of crops

Water productivity was assessed for wheat and rose which were being grown in all the villages as main crops. The current water usage was calculated on basis of information obtained from farmers.

A. Water usage for Wheat

Table 19: Water usage of wheat

VILLAGES	DIESEL PUMP (HP)	TOTAL HEAD (M)	FLOW RATE (L/S)	AREA (HA)	TOTAL WATER SUPPLIED (M3)	CROP YIELD (KG)	WATER PRODUCTIVITY (KG/M3)
Sheikhpura	10	45.72	8.15	2025	1518750.0	800000	0.53
Gadhyampurva	10	76.2	6.11	708.75	227812.5	120000	0.53
Karbi	10	76.2	6.11	506.25	379687.5	200000	0.53
Aima	10	60.96	4.9	303.75	531562.5	315000	0.59

The water usage is calculated on the basis of total water consumed over the entire cropping period. The water productivity is defined as the amount of water required over the entire cropping period to produce one unit of the crop. In this case it has been represented in units of kg of produce per cubic metre

FORMULA USED

Area conversion: Biswa to hectare as per Uttar Pradesh unit.

Water productivity = Total yield/Total water used

CALCULATION

Software used for finding actual water demand: CropWat

Sites: Sheikhpura, Gadiyampura, Karbi and Aima.

Crop considered: Wheat, Rose

volume of water. It can be seen from the table that inspite of having a lower area under wheat cultivation in Aima, the water consumption and yield result in similar water productivity as the other villages even though the yield per hectare is higher than other villages.

B. Water usage for Rose

Table 20: Water usage of rose

VILLAGES	DIESEL PUMP (HP)	TOTAL HEAD (M)	FLOW RATE L/S)	AREA (HA)	TOTAL WATER SUPPLIED (M3)	CROP YIELD (KG)	WATER PRODUCTIVITY(KG/M3)
Sheikhpura	10	45.72	8.15	607.5	163.31	960	5.88
Gadhyampurva	10	76.2	6.11	141.75	28.57	960	33.6
Karbi	10	76.2	6.11	101.25	20.40	960	9.48
Aima	10	60.96	4.9	75.93	12.27	960	78.23
Note: Gadhyampurva, Karbi and Aima farmers also grow vegetables like cauliflower, ridge gourd etc.							

In case of rose, the yield per hectare is highest for Aima and lowest for Sheikhpura. The water productivity is also highest for Aima, while Sheikhpura has the lowest water productivity. This is an indicator of poor soil quality in Sheikhpura and the abundance of water available due to the irrigation being practiced with CETP canal water.

Observation and inferences

- Sheikhpura was completely using canal water for irrigation purpose.
- Gadhyampurva was 20% dependent on canal water whereas other villages were using groundwater for irrigation purpose.

Table 21: Water analysis for downstream villages of Kanpur

Sample	pH	E.C. (mS)	Acidity (mg/l)	Alkalinity (mg/L)	Nitrate (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/l)	T.D.S. (mg/L)	T. S. (mg/L)
Trilokpur (Hand pump) 10/4/2017	6.98	1.53	30	330	22.5	37.96	257.9	1.41	-	1976	2360
Trilokpur (Hand pump) 27/5/2017	7.14	0.8	45	285	23.2	122.46	42.46	0.65	-	1012	568
Garadyampurva (Hand pump) 27/5/2017	7.19	0.8	55	435	0.41	69.97	14.51	1.29	-	944	547
Confluence point (Hand Pump) 10/4/2017	6.78	1.5	60	450	29	53.96	160.5	1.19	-	903	932
Confluence point (Hand Pump) 27/5/2017	7.69	1.5	105	420	31.47	237.42	141.94	0.84	-	1740	1017
Drinking Standard (BIS)	6.5-8.5	-	-	200	45	250	200	1.0	0.3	500	-
Permissible Limit (BIS)	No Relaxation	-	-	600	No relaxation	1000	400	1.5	No relaxation	-	-

4.6 Understanding 'water – soil – crop' interlinkages in Hardoi

Agriculture continues to be the primary source of income in this district. The three main cropping seasons in the district are Kharif, Rabi and Zaid. Sugarcane is the main cash crop and is grown in most parts of the district. The other crops grown in the district include wheat, paddy (rice), maize, pulses, gram and oilseeds. In recent years farmers have shifted from wheat to sugarcane due to the presence of sugar mills in the region and an enabling policy environment that ensured minimum support prize.

Soil and water characteristics

A. Soil analysis

Soil samples were taken from the four villages to gauge the health of the soil in the region.

- Two **soil samples** were taken from each village, one from sugarcane field and one from wheat field. **Physical tests included sieve analysis, soil moisture content while chemical tests included total organic matter content in the soil, electrical conductivity and Nitrogen, Phosphorous and Potassium (NPK) concentrations in the soil**.
- **Groundwater samples** were also taken from the four villages and tests were done to determine the quality of the groundwater at TERI SAS.
- Both the **physical and chemical parameters** testing mentioned above for soil was also done at TERI SAS. Procedure for the water testing was followed as per American Public Health Association (APHA) and (AWWA) guidelines.

Table 22: Soil moisture content of sample fields

Soil moisture content of sample fields (%) Collected in March-April,2017								
	KAZIBADI WHEAT	KAZIBADI SUGAR CANE	BHARKHANI WHEAT	BHARKHANI SUGAR CANE	SEMARGHAT WHEAT	SEMARGHAT SUGAR CANE	KORIGAWAN WHEAT	KORIGAWAN SUGAR CANE
S.M.C	**7.7837**	**7.7430**	**9.1169**	**7.8852**	**4.0732**	**4.6192**	**10.5891**	**14.5332**

Figure 52: Kazibadi sample collection points

Figure 53: Bharkhani sample collection points

Figure 54: Korigawana sample collection points

Figure 55: Semarghat sample collection points

B. *Sieve analysis*

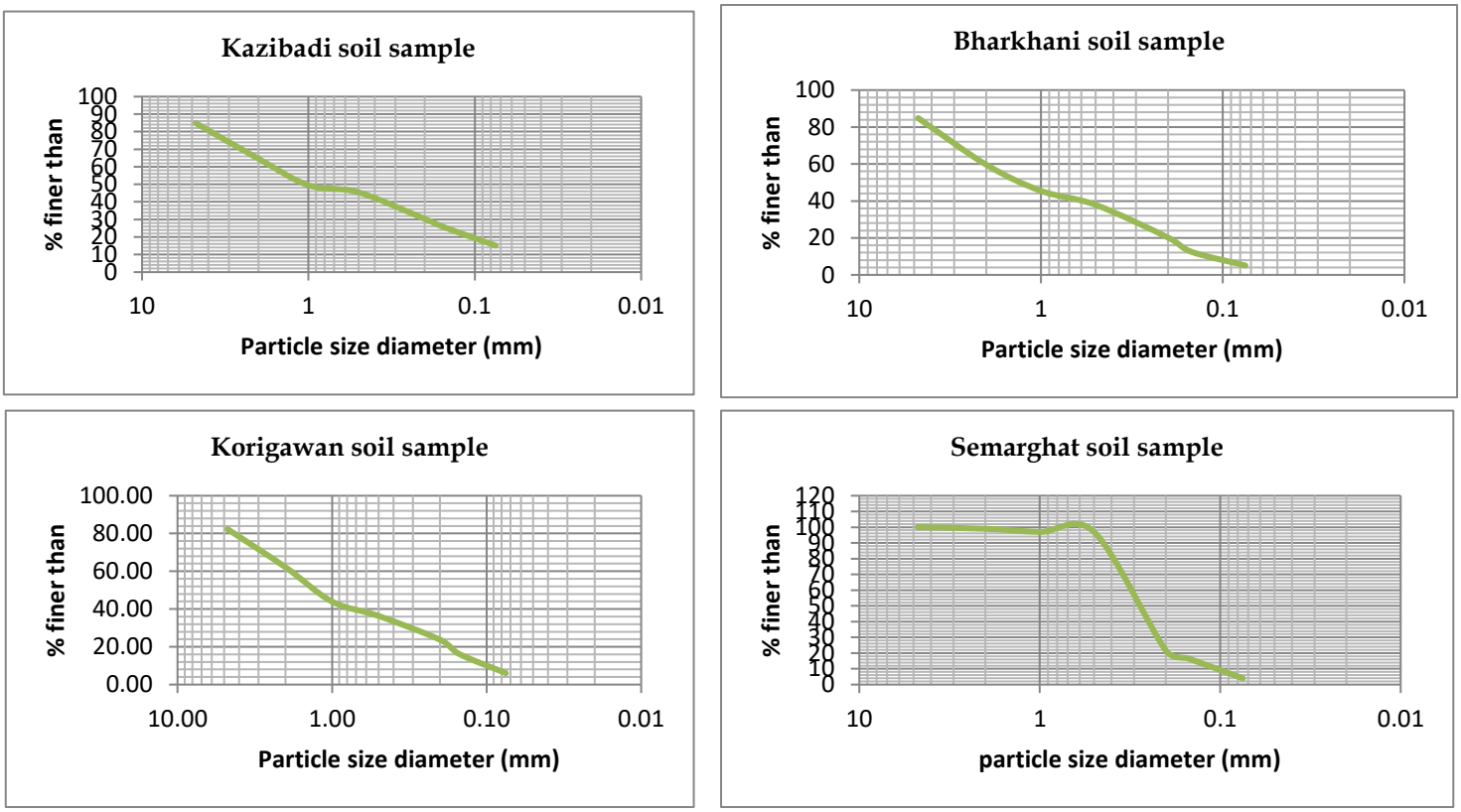


Figure 56: Sieve analysis

The NPK testing was done through Lamotte NPK soil testing kit.

SAMPLE	PARAMETER	KG/ A/6"	ACCORDING TO THE KIT
Kazibadi Wheat	N	18	Low
	P	9	Medium
	K	18	Low
Kazibadi Cane	N	18	Low
	P	9	Medium
	K	18	Low
Bharkhani Wheat	N	18	Low
	P	9	Medium
	K	18	Low
Bharkhani Cane	N	18	Low
	P	9	Medium
	K	18	Low
Semarghat Wheat	N	18	Low
	P	9	Medium
	K	36	Medium
Semarghat Cane	N	18	Low
	P	9	Medium
	K	36	Medium
Korigawan Wheat	N	18	Low
	P	9	Medium
	K	36	Medium
Korigawan Cane	N	18	Low
	P	9	Medium
	K	18	Low

FINDINGS

- Lack of high values for NPK contents indicates that most of the nutrients have been used up during growth period as the soil samples were taken after harvesting.
- No overuse of fertilizers was seen in these 4 villages, which is also seen from the test results.

FARMERS USAGE IN VILLAGE SITES	STANDARD N P K VALUES
➢ **Sugarcane:** 180kg N, 80kg P and 60kg K per hectare ➢ **Wheat:** 80kg N, 40kg P and 30kg K per hectare	➢ **Sugarcane:** 250, 125 and 125 kg per hectare ➢ **Wheat:** 80, 20 and 40 kg per hectare
The soil is healthy	

C. Electrical conductivity

The $EC_{1:5}$ value for the soil to be classified as non-saline is <0.17 dS/m (Summary 2010).

Table 23: Electrical conductivity

SAMPLE	KAZIBADI WHEAT	KAZIBADISUG ARCANE	BHARKHANI WHEAT	BHARKHANI SUGARCANE	SEMARGHAT WHEAT	SEMARGHAT SUGARCANE	KORIGAWAN WHEAT	KORIGAWAN SUGARCANE
E.C. (dS/m)	0.0008	0.0011	0.0009	0.0005	0.0005	0.0032	0.0019	0.0018
Soils present in these villages are not alkaline								

The low electrical conductivity of soils points to less use of fertilisers till now, which is keeping the soil healthy. This may be because these villages have only recently adopted sugarcane cultivation.

D. Organic carbon and organic matter

Table 24: Organic carbon & organic matter

	Percentage easily oxidisable	Total carbon per 100g (%)	Total organic matter per 100g (%)
Korigawan Wheat	0.39	0.55	1.63
Korigawan Sugarcane	0.54	0.7	2.08
Korigawan Wheat	0.81	1.05	3.11
Korigawan, Sugarcane	0.42	0.54	1.60
Semarghat Wheat	0.81	1.05	3.11
Semarghat Sugarcane	0.96	1.25	3.71
Korigawan Wheat	1.29	1.67	4.95
Korigawan Sugarcane	1.44	1.87	5.55

The organic carbon content of the soil in the wheat and sugarcane fields have been determined, this too points to healthy soils and it is important to preserve the soil in such conditions for future too. It is worthwhile to determine the factors which have led to preservation of organic content of soil.

E. Water analysis

PARAMETERS TESTED
Hardness (mg/L as CaCO3), Sulphate (mg/L), Nitrate(mg/L), Alkalinity (mg/L as CaCO3) Acidity (mg/L as CaCO3), Fluoride(mg/L), TS and TDS (mg/L), pH, Electrical Conductivity (mS/m)

Table 25: Water analysis for Hardoi

	Parameters	BIS Standards (drinking water) IS 10500 (2012)	BIS maximum permissible limits	Samples								
				Kazibadi Govt hand pump (120ft)	Sukheta canal Kazibadi	Bharkhani Private hand pump (120ft)	Bharkhani Govt hand pump (120ft)	Semarghat Govt. hand pump (120ft)	River Gomti boundary Semarghat	River Gomti centre Semarghat	Korigawan Private hand pump (200ft)	Korigawan Govt. hand pump (200ft)
1	Hardness (mg/l as $CaCO_3$)	300	600	256	170	334	341	122	194	178	284	281
2	Sulphate (mg/l)	200	400	10.7	38.9	216	211	-	27.5	29.5	33.8	33.7
3	Nitrate (mg/l)	45	No relaxation	-	-	-	-	0.9	0.1	-	3.6	3.6
4	Iron (mg/l)	0.3	No relaxation	0.6	-	5.7	4.15	-	0.1	0.2	-	-
5	Alkalinity (mg/l as $CaCO_3$)	-	-	294	170	398	395	236	204	184	328	330
6	Acidity (mg/l as $CaCO_3$)	-	-	32	16	30	30	12	16	10	42	41
7	Chloride (mg/l)	250	1000	40	5	52	52	45	2	1	45	45
8	Fluoride (mg/l)	1.0	1.5	0.4	0.5	0.4	0.4	0.2	0.5	0.4	0.4	0.4
9	Electrical Conductivity (mS/m)	-	-	0.53	0.38	1.09	1.1	0.25	0.43	0.42	0.81	0.81
10	pH	6.5-8.5	No relaxation	7.1	7.2	6.8	6.8	7.2	7.2	7.2	7	7.1
11	TS(mg/l)	-	-	32.4	20	67.4	67.4	17.5	24.3	31.2	54	56
12	TDS (mg/l)	500	2000	25.3	14	61.8	62.6	16.7	20.2	26.1	39.1	39.2

FINDINGS

- The water test results show that water is of reasonably good quality.
- However, wherever the bore wells are old, not maintained well, rusting has resulted. This is reflected in the iron content of water

4.7 Crop water productivity

Site: Hardoi
Crop: Sugarcane and wheat

- **Groundwater dependence:** The villages of Kazibadi, Bharkhani and Korigawan are completely dependent on groundwater for irrigation as well as domestic purposes.
- **Lack of surface water:** There is no access to any surface water source. Sugarcane and wheat are the dominant crops in these villages.
- **Irrigation techniques:** None of the villages observed were using precision irrigation techniques like drip and sprinkler systems. All the farmers practice traditional furrow irrigation method. Majority of the farmers rely on diesel pump sets of 8 HP, very few use 5 HP electric pumps.

In table 26 is a brief description of the irrigation system at the study sites:

Figure 57: Flood and furrow irrigation

Table 26: Crop water productivity

VILLAGE	TOTAL AREA UNDER IRRIGATION (HA)	AREA UNDER SUGARCANE (HA)	AREA UNDER WHEAT (HA)	BORE DEPTH (FT.)	IRRIGATION EQUIPMENT	BHP	TIME TAKEN TO FILL ONE HECTARE	NO. OF IRRIGATION SCHEDULED	
								Sugar Cane	Wheat
Kazibadi	80	56	24	120	Diesel pump	8	18.5	12	5
Bharkhani	400	160	240	150	Diesel pump	8	24.7	12	5
Korigawan	41	25	16	200	Diesel pump	8	24.7	12	5

According to CROPWAT, the sugarcane (virgin) in our study area should be given a total of 811.1mm of irrigation per hectare. The net irrigation is defined as the field efficiency multiplied by the gross irrigation. But as we are comparing the total irrigation given by the farmers in these

Village	Water supplied to virgin Sugarcane (kl)	Water supplied to Winter Wheat (kl)
Bharkhani	15,87,755.50	9,92,347.20
Semarghat	96,45,614.80	26,79,337.40
Korigawan	1,86,732.00	49,795.00

villages with the CROPWAT values, we will consider the gross irrigation values only, and compare it with the amount of irrigation given by the farmers per hectare in these four villages. The table below showcases the water supplied to sugarcane and wheat by villagers:

The table below is a comparative analysis of water supplied by villagers and actual water requirement calculated according to CROPWAT:

S. No.	Villages	Crop	Diesel Pump(HP)	Total Head(m)	Flow rate(l/s)	Area(ha)	Total water supplied(m3)	Crop yield(kg)	Water productivity(Kl/Kg)	Field efficiency (%)	Actual Supply	Demand (CROPWAT)			Actual water loss
											GWIR per ha mm	NWIR per ha mm	Actual GWIR mm	Actual NWIR mm	
1.	Bharkhani	Sugarcane	8	45.6	9.3	160	1587755.50	11840000.00	0.13	70	992.3	694.6	811.1	567.8	424.5
		Wheat	8	45.6	9.3	240	992347.20	1185168.00	0.83	70	413.5	289.4	346.6	242.7	170.8
2.	Semarghat	Sugarcane	8	45.6	9.3	972	9645614.80	71928000.00	0.13	70	992.3	694.6	811.1	567.8	424.5
		Wheat	8	45.6	9.3	648	2679337.40	3999974.40	0.67	70	413.5	289.4	346.6	242.7	170.8
3.	Korigawan	Sugarcane	8	60.6	7.0	25	186732.00	1850000.00	0.10	70	746.9	635	811.1	567.8	179.1
		Wheat	8	60.6	7.0	16	49795.00	79011.20	0.63	70	311.2	264.6	346.6	242.7	68.5

The water productivity of sugarcane calculated clearly shows that at 0.13 m^3/kg the water consumption is high. This is because of flood irrigation/furrow irrigation that is practiced in the region. The water consumption may be reduced by following water efficient technology.

4.8 Water balance

The water balance in these watersheds will show a **negative result if ground water is used continuously without efficient ground water recharge facilities.** Water bodies in this area have also dried up. Since these are dry watersheds (receive less than annual average rainfall of India), without revival of water bodies, the ground water levels will not be sustainable. Sugarcane has come as a boon in this region, to make it sustainable in the long term, measures to replenish ground water including rain harvesting structures are needed. Currently, ground water is used in the villages under study and ground water seems to be available in abundance. To maintain this abundance, mechanisms like rain water harvesting &, rejuvenation of water bodies will need to be taken up at a large scale.

4.9 Conclusions

The major industry in Kanpur upstream of the villages is the tannery clusters on the banks of river Ganges. The CETP was constructed in the 1990s to cater to the quantity of tannery effluent produced then, the number of tanneries have increased manifold now and the CETP is unable to treat all the effluent, besides the tanneries are also not following certain pretreatment processes which will reduce the toxicity of the effluent reaching the CETP. A reflection of that is seen in the soil-plant-ground water analyses from the downstream villages where the chromium content, sulphate and chloride contents are high. The industry soil crop water interlinkages become important to understand therefore, the various tannery operations and best practices in tannery industry are explained in the case study that follows so that they may be adopted by the industry cluster. Addition of chemicals is a major requirement in the tanning processes, removing these chemicals from the tanneries after processing of hide are a major challenge.

In case of Hardoi, the cropping pattern in the villages have changed to include sugarcane cultivation by using ground water as the neighboring sugar mills provide a ready market for the farmer's produce. The various soil tests, including electrical conductivity and organic content analyses reveal that the soil is in good health though the water consumption is high. If existing water bodies are revived and ground water consumption is reduced then there will be reduced water stress in the future. The case study shows that the sugarcane produced as per the requirement of the neighboring sugar mills of the area and this demand is met by the sugarcane produce from the nearby areas. The industry crop linkages is clear in Hardoi.

Chapter 5
Case Studies on Best Practices from Industries

5.1 The Tanneries of Kanpur

This report comprises a detailed study of tanneries and the effect of tanneries on the river Ganga and the livelihood of the people in the chosen study area in Kanpur. The leather industries have been known to produce highly toxic and lethal effluents that affect the **environment physically, chemically and biologically**.

- The research was conducted in three tanneries based on hides processed per day and classified as small, medium and large tannery.
- This paper evaluates the **various processes involved in the tanneries to convert the raw hide to finished leather product along with the nature of effluents that are produced in the various processes involved**.
- Furthermore, the work environment in the tanneries has been outlined including some of the best practices as observed in one of the tanneries.
- Lastly, the **transition of chromium**; a heavy metal and a key component in tanning and is also carcinogenic if consumed in excess by humans has been discussed in detail.

Classification of Tanneries

For the ease of study, the three chosen tanneries have been classified as small, medium and large tannery. The small tannery processes around 150 hides per day, the medium tannery processes 170 to 200 hides per day and the large tannery processes approximately 250 to 275 hides per day. **The tanneries that were chosen differed in size, process technology used and aesthetic appearance**.

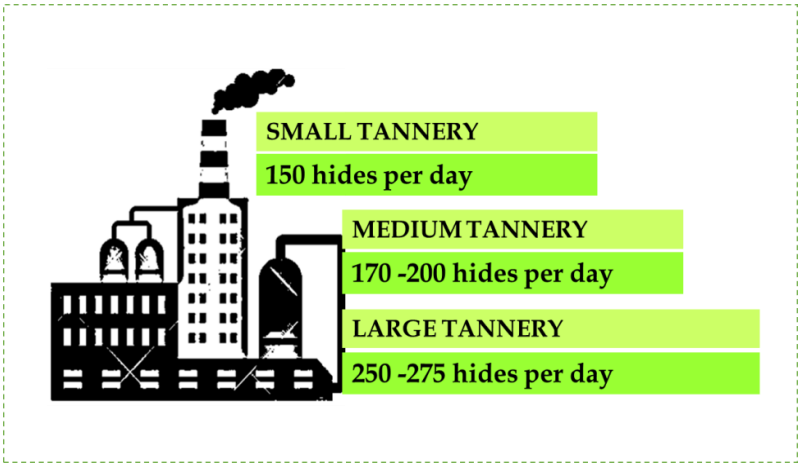


Figure 58: Classification of tanneries

The work environment observed in the three tanneries differed according to the size of the tanneries.

Leather manufacturing process

Pre-tanning process

This process involves a series of operations related to the raw hide. These operations are conducted before the raw hide is tanned in the tanning reagent to form a wet blue.

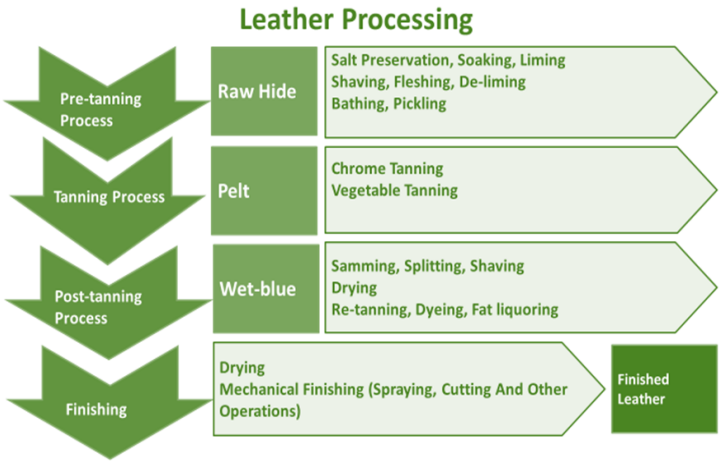


Figure 59: Leather processing

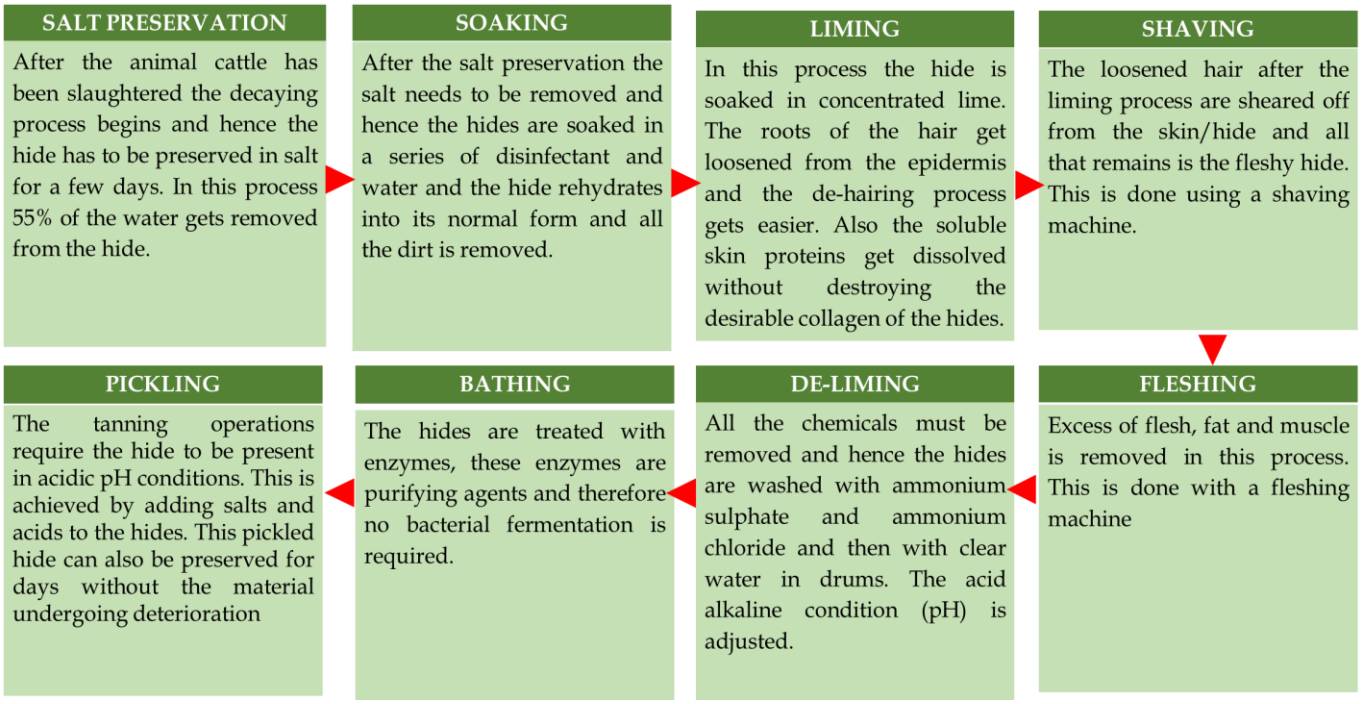


Figure 60: Pre-tanning process

A. Tanning process

Tanning is one of the most critical and important processes in leather processing cycle. This process determines the level of softness or hardness achieved in the leather product. There are two types of tanning process **chrome tanning and vegetable tanning**. After this tanning process, the hide is no

longer susceptible to rotting, and the product obtained after tanning is called the wet blue. ***This process is carried in drums which are rotated continuously for even tanning.***

CHROME TANNING	VEGETABLE TANNING
Tanning is done using basic chromium sulphate in its trivalent form. This reagent is used for tanning when the final leather product is desired to be soft. Being a heavy metal and chromium is carcinogenic in nature, this process is widely criticized. However, to achieve a soft leather product like a jacket or a sofa cover, chrome tanning is the only way to achieve the same.	Vegetable tanning is an age-old process devised to tan the raw hide using vegetation extracts like wood-bark, vegetable extracts and other elements. It is an **environment friendly process** as no chemical is used and is purely organic and the vegetable tannin can be recycled. This tanning procedure is used to achieve a hard leather product like dog-chews and horse-saddles.

B. Post-Tanning Processes

After the completion of the tanning process, the wet blue that is obtained must undergo seven stages of operations starting from dry milling, snuffling, buffing, spraying, cutting, lacquer coating before the finishing operations are carried out.

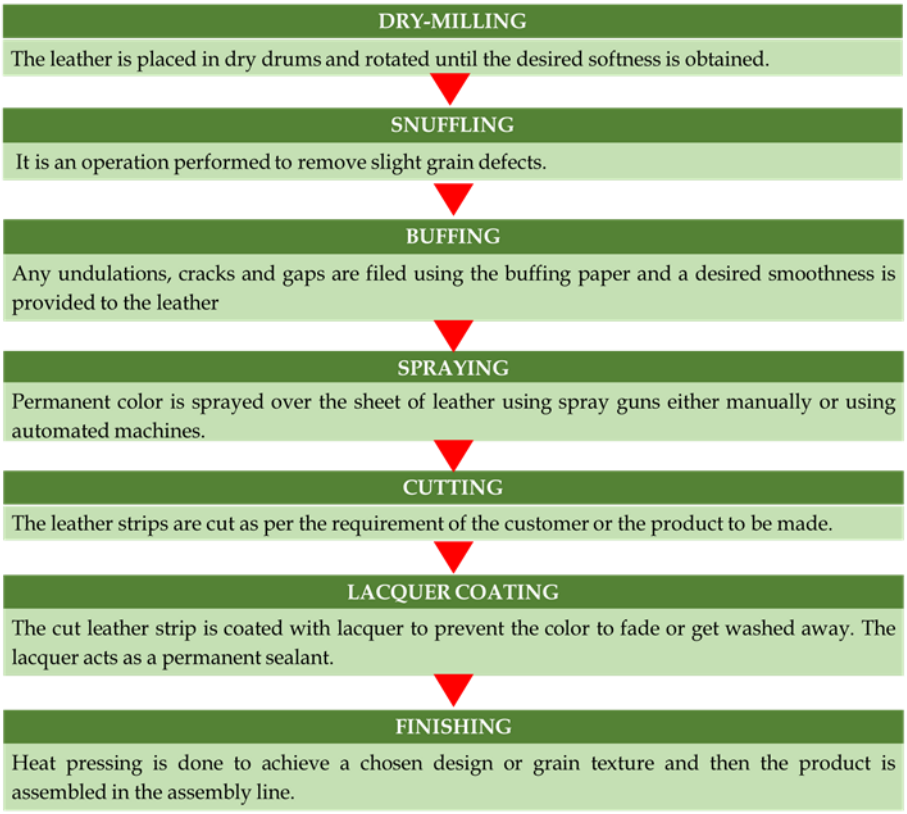


Figure 61: Post-tanning processes

C. Finishing processes

The dyed wet blue must undergo a series of operations to be transformed into a finished product ready to use.

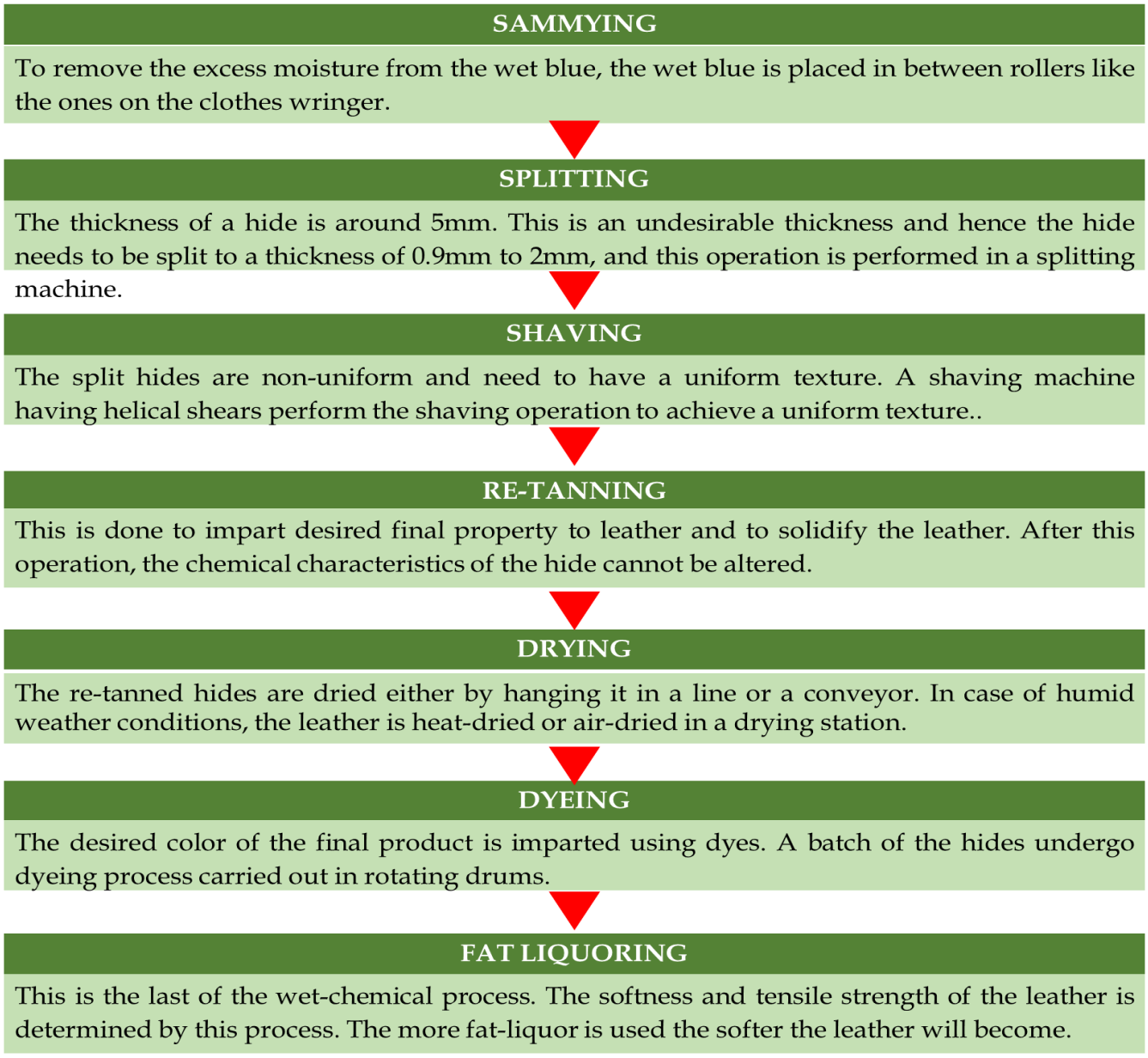
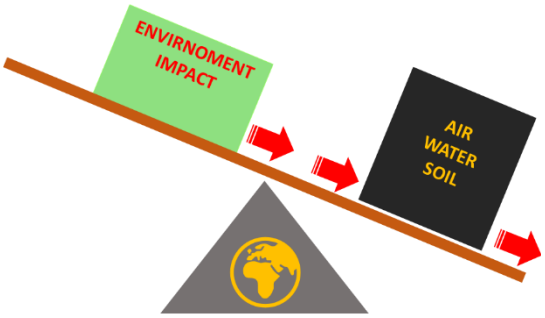


Figure 62: Finishing processes

Nature of effluents in Tanneries



Each of the major processes in the leather industry produces waste in the form of solid, liquid and gas. These wastes are sometimes recovered, reused, treated or discarded based on its usability and impact on environment.

PRE-TANNING PROCESS	TANNING PROCESS
➢ This process generates waste in the form of solid, liquid and gas. ➢ The solid waste comprises dusted salts, trimmings, flesh and hair. ➢ These solids waste are used in making glue and bio-fertilizers. ➢ The effluents contain salt water, lime water and proteins. Sulphide is generated as a gaseous form of waste.	➢ The tanning process generates salts and chrome in the effluent form and vegetable extract if vegetable tanning is used. ➢ The chrome is at times recovered and reused if the appropriate technology is available with the industry.
POST TANNING PROCESS	**FINISHING PROCESS**
➢ The post tanning process generates waste in the form of splits and shavings as solid waste and dye, grease, synthetic-tans and chrome as liquid waste. ➢ This waste is sometimes reused or discarded subject to the usability of the waste after the operation.	➢ Tanning waste and buffing dust are generated as solid waste and particle buffing dust, formaldehyde gas and organic solvent gas are generated as gaseous waste. ➢ The gaseous waste is released into the air by high-raised chimneys.

Solid waste management of tanneries in Kanpur

The solid waste such as trimmings, flesh and hair are used to make glue, bio-fertilizer, furniture varnishes and many other products. The waste generated out of the leather like buffing dust, splits, shavings cuttings etc. are transported to the site where they are converted into chicken feed and manure. The leather waste is burnt in furnaces to a point where it is reduced to organic product like chicken feed and manure. This manure is transported to many parts of the country to be used for farming purposes. The production of chicken feed is temporarily discontinued in Kanpur as it would lead to biological magnification because of the presence of chrome in the product and chromium consumption in excess is carcinogenic in nature. As for the environmental impact, the process pollutes the environment in three dimensions.

Figure 63: Tanneries solid waste management site

- **Air pollution:** Due to the release of gases during the heating of the leather in the furnace air pollution takes place.
- **Water and soil pollution:** The unwanted waste is discarded directly into the river Ganges polluting its water and excess use of the chrome laden manure pollutes the soil

Work environment and best practices in tanneries

The tanneries in Kanpur majorly comprised small and medium sized tanneries. Hence, their technological input and the work environment were completely different from the larger tanneries in Unnao. The smaller tanneries were found to be deprived of space and hence the operations sites were positioned non-uniformly and were unorganized. Some of the observations included:

- Manual application of salt on hides
- No chrome recovery units were found
- The workers were seen to work without gloves or protective gears
- Hazardous chemicals were not stored in designated safe spaces
- Primary effluent treatment plants were small.

Figure 64: Work Environment in smaller tanneries

The larger tanneries were not only technologically advanced but also very worker friendly. Some even followed best practices in the operations for leather processing.

Some observed best practices are as follows:

- Chrome recovery unit.
- Salt shaker machine.
- Hair removal machine and the extracted hair is sent for biomass production.
- Vegetable tanning used for hard leather products like dog-chews and horse-saddles.
- Lime recovery units.
- Water meter at source and outlet.
- Rainwater harvesting unit.
- Heating station for drying leather powered by solar photovoltaics.
- Conveyor belt for drying leather run by a 1 HP motor.
- Use of protective gears and masks.
- Safe storage of hazardous chemicals.

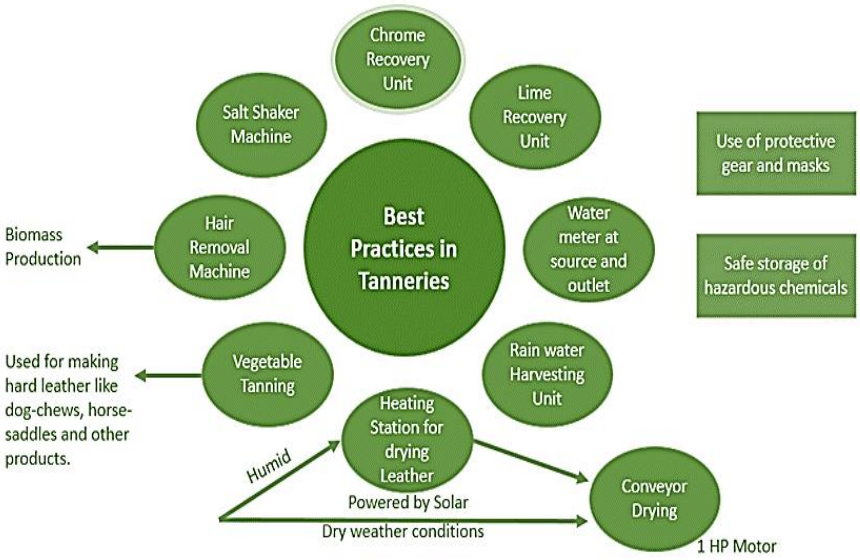


Figure 65: Best practices in tanneries

Chrome recovery

Chrome is extensively used in the tanning of hides. Chrome being a heavy metal, carcinogenic in nature can be lethal to both humans and environment if it is used unsustainably. Hence a chrome recovery unit is a mandatory requirement in tanneries that use chrome tanning, so that after the tanning process, the chrome is recovered from the effluent and used in the subsequent cycles

Figure 66: Chrome recovery plant

Chrome recovery process: The excess chrome tanned effluent is collected in a bath called the **exhausted chrome bath.** This effluent is then sent to a reactor where magnesium oxide is added to it. Here the chrome is in hexavalent form having a pH of 11, but the tanning process requires the chrome to be present in its trivalent state because the hexavalent chrome is thermodynamically very unstable. Hence the solution obtained in the reactor is sedimented in a conical bath wherein the magnesium precipitates are collected in the conical bath and the solution is transferred into the acidification tank. The acidification takes place with the addition of conc.H2SO4 The settling takes for 48 hours in a settling tank. Here the pH of the solution is three and the chrome is in its trivalent state. The chrome is then extracted and stored in chrome storage tanks. The extracted chrome can be recovered and reused for at most three cycles and then needs to be discarded.

If the best practices adopted by larger tanneries can be adopted in smaller tanneries as well, as a cluster then the industry will become sustainable. Efforts are going on to address these issues and find out effective solutions

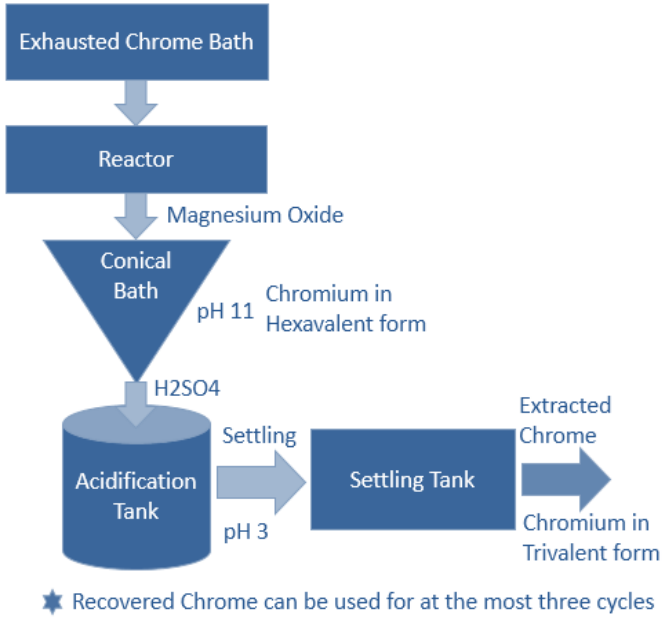


Figure 67: Chrome recovery process

5.2 Sugar mills in Hardoi

Sugar cane is grown in Hardoi district as sugar mills are located within the district near the villages. Sugar mills of DSCL are, located at Ajbapur in Lakhimpur Kheri District, followed by other manufacturing units at Rupapur, Hariawan and Loni, in Hardoi District. Presently, DSCL is working with approximately 1.5 lakh farmers and have an installed capacity of 33,000 TCD (tonnes of cane crushed per day). With the aim of farmers maximizing their sugar cane yield and produce quality, Sugarcane experts from the mills are engaged in the command area who interact with farmers on a regular basis. They are actively engaged with the farming community to share adopted best practices such as mulching, furrow irrigation including how techniques to contain pest attacks. The Bio Control Lab in the Rupapur Sugar Unit is also assisting farmers in controlling/checking pest attacks through cultivating and releasing parasitoids that control plant pests and helping in improving the ecological balance.

Figure 68: Water Meters, DSCL Sugar

Figure 69: Test beds for mulching, DSCL Sugar, Loni, Hardoi

Sugar cane is grown within factory premises also, so that similar conditions as farm fields are simulated and research may be carried out on mulching, control of ground water usage. Water meters are placed along the fields to monitor the groundwater usage per irrigation. Furrow irrigation and mulching is practiced in these sugarcane fields to reduce evaporation losses so that less water is consumed. **Hardoi is a semi-arid region thus preservation of soil moisture will lead to sustainable agriculture.**

Figure 70: Bio Control Lab in the Rupapur

The production facilities have co-generation power plants, based on bagasse, a by-product in the sugar manufacturing process. The capacity of the installed co-generation[1] plants is 115 MW, which is used for in-house consumption and the excess energy produced is transferred to the national grid.

Figure 71: Test beds for furrow irrigation, DSCL Sugar, Loni, Hardoi

Sugarcane production in Hardoi region is driven by the capacity of the sugar mills. Each sugar mill is assigned a command area[2] and they procure sugarcane from farmers who grow sugarcane specifically for their sugar mills. Besides, the mills also procure sugarcane from farmers who come at

[1] Co-generation is the concept of producing two forms of energy from one fuel. One of the forms of energy must always be heat and the other may be electrical or mechanical energy. In a conventional power plant, fuel is burnt in a boiler to generate high-pressure steam which is used to drive a turbine, which in turn drives an alternator through a steam turbine to produce electrical power. The exhaust steam is generally condensed to water which goes back to the boiler. As the low-pressure steam has a large quantum of heat which is lost in the process of condensing, the efficiency of conventional power plants is only around 35%. In a cogeneration plant, very high efficiency levels, in the range of 75%–90%, can be reached. This is so, because the low-pressure exhaust steam coming out of the turbine is not condensed, but used for heating purposes in factories or houses (http://www.indiansugar.com/Cogeneration.aspx).

[2] Command Area - Each sugar mill is allocated a command area in its vicinity (which usually varies from 15 km to 25 km radius, depending on the state). The mill is bound to purchase any sugarcane grown in that area. Sugarcane farmers are also expected to sell only to the designated mill.

the gate of the sugar mill to sell sugarcane. Typically, mills in Hardoi work from November to April as sugarcane is harvested either in winters or early summers. Sugar mills shut down between May to October and this time is used for carrying out the preventive maintenance of the mills. The major source of water for irrigation and consumption in the sugar mills in the region is ground water.

Figure 72: CSR by DSCL Sugar in Hardoi

The sugar produced from the sugarcane is one of the highest in the country. The considerable number of sugar mills in the region has seen farmers switching over to growing sugarcane as it fetches them a better price for their produce. **The mill owners continuously engage with farmers to train them in efficient farm practices and water use efficiency.**

Corporate social responsibility

As part of the corporate social responsibility, the mills work along with ASHA and Anganwadi workers to spread awareness about preventive healthcare. They also actively contribute towards the Swachh Baharat Mission of the Government of India by constructing toilets in the government schools which form part of their command area and organizing training programmes on maintenance of these toilets. As part of the rural development initiative, they support various culvert and road renovation projects, providing financial aid for sinking bore wells, trash mulching and school building renovation. They further contribute towards environment sustainability by way of planting trees and distributing bio-compost (the press mud generated as one of the by-products).

Figure 73: Sugar mills in Hardoi

Chapter 6
CONCLUSIONS & RECOMMENDATIONS

Landscape approach calls for reconciliation between the conservation and development objectives with the aim of balancing socio-economic and environmental outcomes in any geographical context. In the mid-Ganga context under discussion, which is under twin pressures from agriculture and industrial and urban expansion, managing the multi-functionality along with sustainability is a vast challenge. The land use and soil and water analysis in this region showed several trends like: shrinking green cover; decline in water bodies and ground water table; chromium and salinity problems in canal water that is used for irrigation; concern with water balance in watersheds in future within the current scenario of water use and management.

Land use/land cover change and its impact on existing water resource

The land use/ land cover change analysis of the region suggests that the different transitions has a significant impact on the current water resources. In both industrial belt as well as sugarcane belt there has been increase in surface run off and decline in ground water recharge due to decline in total vegetated cover. Therefore, there is need to put effort in the direction of development of green belt around Ganga.

Specifically, in Kanpur district, there has been increase in urban area and decline in cultivated land over last one decade. The overall loss in vegetated land for urban expansion has led to decline in groundwater recharge capability of the area. Although currently not so significant, but the increase in surface run-off and decline in ground water recharge, if continued, could have serious impact on agricultural activities where groundwater is the main source for irrigation. The study also shows that there has been decline in the groundwater table due to withdrawal for irrigation in absence of canal network in the area and industrial use (around 400 leather tanning industries withdraw groundwater for their processing operations).

In Hardoi district and Mohammadi tehsil of Lakhimpur, most of the land use/land cover transition has occurred in the western part of the region that lack proper canal network and groundwater resources. Loss of vegetated cover and increase in fallow land in the study area has led to reduction in soil infiltration capability. Thus, there is an increase in the runoff potential and decline in the groundwater recharge in all three watersheds. The study also shows a decline in the water bodies

that were present in the southern tehsil of Hardoi district. Therefore, an extension of the canal in the western part and the revival of water bodies could be considered in this region.

Soil – water – crop interlinkages

In Kanpur, the study showed an increased level of chromium in soil, plant roots and shoots adjacent to CETP canal. As one moves away from the immediate vicinity of the canal, the soil and plants both exhibit low chromium content. This has enabled the villages to grow flowers, clearly showing a linkage between water quality-soil conditions and cropping patterns.

Both chromium and salinity problems in the canal water flowing from CETP are closely linked to industrial practices. While the CETP capacity has not been enhanced, there has been unregulated increase in the number of tanneries. Removal of chemicals used in the tanning processes after processing of hide is also a major challenge. **Therefore, it is recommended that by following best practices as shown in the Kanpur tannery case study, pretreatment of effluent may be practiced before it reaches the CETP inlet.**

However, in Hardoi the cropping pattern in the villages is gradually changing to include sugarcane cultivation as the neighboring sugar mills provide a ready market for the farmer's produce. **Since sugarcane cultivation requires intensive irrigation, more groundwater is extracted.** The results from various soil tests, including electrical conductivity and organic content analyses reveal that the soil is in good health though the water consumption is high. The study area fell under a semi-arid zone, **it is recommended to revive existing water bodies and reduce groundwater consumption to address water stress condition that may develop in near future.**

Though the farmers in Hardoi have shifted to sugarcane cultivation, the soil nutrient balance does not seem to be too adversely affected. This could be because such shift is recent and at smaller scale. However, it is important to consider that this area of Hardoi is not served by Sharda canal and is entirely dependent on ground water. The surface water bodies have also dried up in absence of proper management. Therefore, in the absence of any artificial recharge facilities, this could be a cause of concern in future and impact productivity. The following analyses were drawn from the soil, water and plant sample tests.

- Lack of high values for NPK contents indicates that most of the nutrients have been used up during growth period as the soil samples were taken after harvesting. Therefore, soil is healthy with low electrical conductivity.

- No overuse of fertilizers was seen in these 4 villages, which is also seen from the test results of soil organic carbon content.
- The ground water test results show that water is of reasonably excellent quality as per the test parameter which are below standard limits. However, wherever the bore wells are old, not maintained well, rusting has resulted. This is reflected in the iron content of water.
- The water balance in these watersheds will show a negative result if ground water is used continuously without efficient ground water recharge facilities.

Community resource interactions

The socio-economic and institutional analysis added complexities to the above findings and suggests that given these ecological trends, if the institutional intermediation does not address the socio-economic vulnerabilities, it will lead to further marginalization of certain communities and enhance resource degradation. **The parameters for micro/village level analysis included livelihood sources and income, food and water availability, asset holding, agricultural practices and backward and forward linkages, settlement type, sanitation and waste management facilities, health/health infrastructure, education, institutional opportunities and participation, gender roles and women's inclusion and resource management practices.**

The findings from Hardoi and Mohammadi tehsil of Lakhimpur showed that most of the income was from farming but it was highly subject to risks in absence of institutional credit, market institutions, storage infrastructure and resultant low bargaining power. The major crops grown in this area included wheat and sugarcane; but there was greater willingness to shift to sugarcane due to assured market and higher prices. This would benefit the farmers but concerns like lack of irrigation facilities, groundwater abstraction cost, energy prices, institutional credit requirements and weather risks might enable the better off farmers to gain in the long run. In absence of appropriate institutions, resource sustainability would be threatened by declining vegetative cover and diversity, dying surface water bodies, groundwater abstraction rate, recharge rate and energy subsidies. The study also showed that the socio-economic status was strongly influenced by caste and gender dimensions. Thus, land distribution was skewed in favor of the General and OBC categories while women did not have property rights. Institutions were weak and participation in institutions was nominal, particularly for the lower caste groups. The Panchayat was not active and thus even minor village disputes were taken to the police. Women were mostly uneducated and faced restricted participation in workforce, market and political institutions. Their role in decision

making at household level was meagre and faded at community level. Thus, even though they were closest to the resource albeit in a nurturing role, they were "absent" from the community and resource based institutions. Social infrastructure was poor as studied through literacy status, awareness levels, access to health institutions, and social capital. The study did not locate any intervention through civil society organizations in any of these realms.

The study in Kanpur showed that the area was better endowed in terms of physical infrastructure but ridden with complex caste dynamics. This was reflected in various dimensions of economic well-being, where the General and the OBC categories were better off in terms of occupational diversity, land holding size, asset ownership, and livestock holding. Agriculture was primary occupation for General category farmers, while others supported their income from other sources like labour, employment in tanneries and other unorganized units. Crop diversity was noticeable where farmers were also engaged in floriculture (particularly roses) along with regular crops like wheat and *jowar.* Yet, agriculture remained mostly of subsistence nature due to lack of backward and forward linkages. In absence of storage infrastructure and formal marketing linkages, farmers had low bargaining power. In addition to agriculture, livestock rearing also yielded a steady income but in absence of organized market for sale of milk and institutional support, this remained as a subsidiary source of income only. Unlike Hardoi and Lakhimpur Kheri, access to formal financial institution was better but savings and investment habit seemed lacking, even amongst those with steady source of income. Resource management practices and institutional support for the same could result in not just scarcity in future but further socio-economic vulnerability. In Aima, groundwater was used for drinking and irrigation purposes. While water table was reportedly receding and issues of quality surfaced, there were perceptible caste based differences where the high-income households could address quality issues by abstracting 'sweet' water from 150 to 180 feet while low income groups could not. Surface water sources were filled, eutrophied or dried up due to mismanagement. In Sheikhpura, farmers used CETP canal water for irrigation. They reported using less fertilizer owing to the presence of heavy metals in water that gave 'a lot of power', but used more pesticides since the crops were prone to pest attacks. While incidence of both chronic and common ailments was common to both areas, there was a perceived correlation (which could not be statistically verified) between canal water and health conditions in Sheikhpura.

The access to social infrastructure (in terms of schools, markets, institutional linkages etc.) was better than Hardoi and Lakhimpur Kheri, yet institutionally the study villages did not seem robust as reflected through participation rate, accountability mechanisms and existing social capital. Women came closest to the natural resources, but their role in managing natural resources was

limited. They had no access to property; they were 'missing' from institutions; and lacked a 'voice' even after affirmative steps through reservation. The social set up was so replete with gender stereotypes that women themselves had started perceiving their insignificance in institutional matters, often labeling it as 'a man's business'. The study could not see active involvement of women in community level decisions.

Overall, the socio-economic and gender analysis at the village level, with reference to natural resources (specifically water resource) suggests that the development planning in the region has not adequately considered the socio-economic vulnerability of the local communities and therefore decisions pertaining to trade-offs prioritize certain land use over 'not so productive' use (like agriculture in many places). Agriculture itself is highly politicized agenda in the state, whereby, certain sections 'capture' the subsidized resource access (state has free electricity in many areas; there is no regulation pertaining to groundwater use; procedure for institutional credit is unclear); while others still await even basic irrigation and credit requirements. In Kanpur, some of the farmers have also sold land preempting industrial sector growth. Considering low productivity and absence of jobs, the youth are willing to engage in other occupations and migrate to the city. This is indicative of the larger trend where we also see expansion of the urban sprawls and declining green cover.

The overall scenario suggests that the resource governance considerations need to factor the socio-economic vulnerabilities, livelihood diversification and backward and forward linkages for agriculture. In the long run inventions require greater stakeholder engagement, effective governance structure and better institutional coordination. More specific decisions pertaining to resource need to address efficiency issues and institutional coordination. The sugar mill study is a case in point where they seem to be adopting a 'co-benefit' approach while working with the farmers, thus not just providing a market for produce but also promoting better resource management practices like mulching etc. The study of tannery suggests techno-political interventions with a mix of better treatment facilities and stricter regulations and enforcement mechanisms. The study has tried to amalgamate various considerations through the landscape principles that is illustrated in a matrix form (with broad and specific recommendations) given below.

PRINCIPLE 1 & 2: RECOMMENDATIONS	
Continual learning and adaptive management	***Broad Recommendations:*** ➢ Changes in landscape attributes (ecological, land use and socio-economic changes) must inform decision-making. ➢ Dynamic interactions across scale to foster new understanding and knowledge which become a basis for revised strategies. ***Specific Recommendations:*** ➢ Continuous research to enhance sustainable production (particularly sugarcane) and to suggest crop rotation to maintain the soil health. ➢ Rejuvenation of water bodies which shall maintain water balance in the area. ➢ Capacity building of government and other staff on best practices in agriculture under changing soil and water conditions
Common concern entry point	***Broad Recommendations:*** ➢ Understanding & accepting different stakeholder interest, diverse values & beliefs. ➢ Adopt socio-ecological approach to address socio-economic vulnerabilities and resource degradation ***Specific Recommendations:*** ➢ Address water demand and management issues through extending/reviving canal networks in the south-western side; strengthening ground water management with allocation system; recharge through abandoned wells ➢ Extend infrastructure and institutional support for farming (reference to storage facility, institutional credit and market linkages could be an excellent entry point to sustainable farming technique adoption among farmers) ➢ Initiate interventions on allied livelihood options (opportunity for animal husbandry-by taking care of breed improvement, veterinary services, marketing and pricing aspects).

PRINCIPLE 3,4 & 5: RECOMMENDATIONS	
Multiple scale	***Broad recommendations***: ➢ Cross-scale participatory planning; inclusion of independent experts, organizations and local participants that can facilitate exchange of learnings ➢ Spatio-temporal mapping to capture the changes in natural resource and adapt planning in accordance with resource status. ➢ Development of 'bottom- up' community intervention strategies to

	improve land use practices ***Specific recommendations:*** ➢ Spatial mapping using multiple resolution earth observation dataset (few centimeters to few kilometers spatial resolution) ➢ Water allocation must be decided at each level (village, panchayat/municipality and industry) and collectively as well ➢ Creating awareness and including citizens in resource monitoring and planning
Multi functionality	***Broad recommendations:*** ➢ Change in vision on agriculture from "cultivated landscapes" to multi-valued socio-ecological units/multi-functional socio-ecosystems ➢ Proper assessment and valuation of ecosystem services at landscape level (including water, land, vegetation) to plan for better risk diversification ➢ Building a green corridor along the river Ganges at Kanpur, along with decentralized treatment facilities. ***Specific recommendations:*** ➢ The potential of floriculture and agro-forestry remains unexplored-this could be taken up to support household income. ➢ Diversify from pure farm based livelihood system to allied and non-farm occupation (like livestock rearing, small enterprise development) ➢ Quality of treated tannery effluent, which is used for agriculture, needs to be improved and its health impacts must be properly assessed ➢ Continuous monitoring and assessment of crop productivity (particularly sugarcane) to improve crop yield through proper management rather than being focused on cultivated area expansion.
Multi stakeholder	***Broad recommendations:*** ➢ An area/landscape planning approach that brings together all stakeholders and mobilizes resources ➢ Create multi-stakeholder dialogue platforms that brings together stakeholders ***Specific recommendations***: ➢ ***Kanpur:*** Include Panchayat members (with representation from all caste groups), Kanpur Nagar Nigam officials, tannery owners and CETP officials in seasonal water allocation and management planning ➢ ***Hardoi:*** Include Panchayat members (with representation from all caste groups), Block Development official, Sugarcane commissioner, Sugar mill owners, Irrigation Department in seasonal water allocation and management planning ➢ Create local institutions with active involvement of NGOs/CSOs to generate awareness on soil and water quality, build capacity for resource monitoring and management and ensure equitable resource allocation.

PRINCIPLE 6, 7 & 8: RECOMMENDATIONS	
Negotiated and transparent change logic	***Broad recommendations:*** ➢ Need to generate higher social capital; better accountability mechanisms; higher transparency in functioning of state and non-state units ➢ Institutional measures more important- stricter real-time monitoring framework linking it to graduated sanctions (this must be a participatory effort) ***Specific recommendations:*** ➢ Capacity building of farmers and other stakeholders through regular trainings and workshops, to understand the resource condition, trends and involved in regular monitoring of resource ➢ Improving governance by clear accountability mechanisms; ensuring transparency in projects and planning; grievance redressal mechanisms to be developed with proper access rules.
Clarification of rights and responsibilities	***Broad recommendations:*** ➢ Creating a state level autonomous institution that becomes the nodal agency for coordination, planning, monitoring, compliance and dispute resolution. The scope for planning for this agency should be at a watershed scale. ➢ It becomes the mandate of this institution to consult all stakeholders (including local institutions), assess and prioritize demands based on resource condition and maintain a centralized database which is also freely accessible to the public. ➢ This autonomous institution can create sub-units for enforcement and monitoring at district/block or other levels, as required. ➢ Clear tenurial rights, including focus on women's property rights ***Specific recommendations:*** ➢ Well-defined resource and institutional boundaries- ensure that every person/institution has clarity on his/her rights and responsibilities ➢ Well-defined property rights with equal entitlement for male and female members of the household. ➢ Considering close interaction of women with natural resources, stress on greater women membership and involvement in village institutions and decision making
Participatory and user-friendly monitoring	***Broad recommendations:*** ➢ Local stakeholders and government agencies can learn and adapt together ➢ Recognizing validity of different knowledge systems- Collecting and managing data from multiple sources that can be integrated and information thus created can be used by various stakeholders ➢ Developing citizen science based approach for continuous resource monitoring and adaptive planning

	Specific recommendations: ➢ Creating mobile app which can be used by citizens to provide data at appropriate scales ➢ Capacity building amongst stakeholders to monitor and interpret water and soil quality parameters and adapt land use practices ➢ Affirmative steps to include villagers and women in decision making

PRINCIPLE 9 & 10: RECOMMENDATIONS	
Resilience	***Broad recommendations:*** ➢ Ecological resilience ➢ Maintaining soil and water health through active monitoring and restoration mechanisms ➢ Devising a landscape level geo-spatial framework for continuous annual scale monitoring of general land use, crop patterns and water resources with threshold based alert systems ➢ Community resilience: ➢ Enabling risk diversification mechanisms through livelihood interventions ➢ Ensuring backward and forward linkages where farming is practiced ***Specific recommendations:*** ➢ Considering semi-arid characteristics in Hardoi, preservation of natural soil nutrient levels is crucial to ensure resilience ➢ Use of mulch, manure from sugar mills, produced as by product in sugar mills to maintain sustainable soil moisture and nutrient levels. ➢ Rejuvenation/restoration of dried up surface water bodies to ensure continuous water supply ➢ Active consideration of groundwater recharge to maintain sustainable ground water levels ➢ Regular monitoring of water and soil quality and impact of effluents on crops and health of farmers ➢ Regular monitoring of cropping pattern and providing suggestion on right mix of crops ➢ Floriculture in Kanpur region should be encouraged considering high salinity and presence of chromium in effluent canal water that is used for agriculture ➢ Proactive intervention in alternative livelihood sources (allied and non-farm activities- for example: livestock rearing, small enterprise development) to support household income levels ➢ Promote self-help groups and other local institutional interventions to mobilize farmers and promote collective action ➢ Ensure better risk preparedness among women members (through education, capacity building and property rights)
Strengthened stakeholder	***Broad recommendations:*** ➢ Strengthened stakeholder (including local institutions) capacity for

capability	participatory resource mapping, data assimilation and database management ➢ Need to increase literacy level and educate farmers on resource use efficiency ➢ Active education programmes and skill building particularly among the youth groups to enhance employability ***Specific recommendations:*** ➢ Skill training, capacity building among different government and local institutions on resource management, monitoring and citizen science approaches ➢ Enable handholding to small tanneries and industrial units for decentralized waste treatment facilities ➢ Encourage local innovations and development of 'bottom- top' community intervention strategies to improve land use practices ➢ Awareness strategies for water conservation. Educating citizens on depleting soil and water resources

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