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Land Evaluation for Land Use Planning towards Sustainable Crop Production: A Case Study of *Chhata tehsil* in Mathura District, Uttar Pradesh, India

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A B S T R A C T

The land resources of Chhata tehsil of Mathura district, Uttar Pradesh, India was evaluated for land use planning towards sustainable crop production. The land evaluation is crucial for food security, economic growth and overall development of the nation. Currently, land is being subjected to various kinds of degradations, which calls for its evaluation viz., land capability and land irrigability classification for various land uses. Soils of the study area belong to Inceptisols and Entisols orders. Soils were grouped into 9 soil series, categorized under four land capability classes (II, III, IV and VII) and 8 land capability sub-classes, suitable for crop production as well as silvi-pastoral development. Besides, 4 land irrigability classes and 6 sub-classes were also identified based on the degree of soil limitations for sustained use under irrigation. Socio-economic survey revealed the predominance of rice-wheat cropping system in the area. The results indicated higher average crops yield under large land holding categories among and across the soil series. Amongst all land holdings, highest yield was observed in Garhsauli series for rice, Ladpur series for wheat and sorghum, Simri series for mustard, pearl millet and cotton and Chhata series for sugarcane, respectively. Rice and pearl millet during *Kharif* season for Garhsauli and Simri series and mustard during *rabi* season for Simri series are the most suitable land use plans under all land holding categories.

Introduction

Land is one of the scarce resources and plays a pivotal role in food security, economic growth and overall development of the nation. Land in many areas of the world is seriously affected due to various kinds of land degradation. According to an estimate of ICAR and NAAS, New Delhi (2010) about 120 m ha area of India is subjected to several types of land degradation. It occurred largely due to indiscriminate land use practices (FAO, 1985; Raji, 1999), which calls for reliable land evaluation. Land evaluation is a tool for land use planning towards sustainable agriculture (Shahbazi *et al.*, 2009; Perveen *et al.*, 2012). It is a process of predicting land performance over time according to the specific types of use (Zonneveld, 1989; Rossiter, 1996; Lee and

Yeh, 2009; Martin and Saha, 2009; Sonneveld *et al.*, 2010). Land evaluation is the rating of soils for optimum returns per unit area (FAO, 1976; Wambeke and Rossiter, 1987) and provides information on the major constraints as well as opportunities for land use. It enables the land users and land use planners to develop crop management approaches to increase the productivity. Land evaluation is carried out for several parameters viz., land capability class, land irrigability class, soil suitability analysis and land use planning.

Land capability is inherent capacity of land to perform at a given level for a general use (FAO, 1976). Classification is largely based on the capability or limitations (U.S. Soil Conservation Service, 1958, 1959, 1963 & 1992). Land capability class acts as a useful guide for precise land utilization types under different soil, climate, topographic and other attributes of land. While, land irrigability is of paramount importance to predict the behaviour of soils under the changing water regime brought about by the introduction of irrigation. It is mainly defined in terms of degree of soil limitations and useful in grouping the soils according to their suitability for sustained use under irrigation. Land irrigability classification is based on soil characteristics viz., soil texture and depth, available water holding capacity, infiltration and permeability (All India Soil and Land Use Survey Organization, 1970). Besides, land evaluation needs to be done for soils to assess their suitability for agriculture under the present conditions of depleting soil organic carbon reserve, salinity, alkalinity and erosion hazards. Evaluation of land resources is required to develop the productive land use systems with proper attention towards new cropping sequences for sustainable crop production and diversification so as to meet the ever increasing demand for cereals, vegetables, pulses and oilseeds (Newaj and Yadav, 1992).The most important aspect of land evaluation is land use planning, which suggest best use of agriculture lands to most suited crops as well as other economic uses at various scales.

Land use planning is highly desired technology for a nation like India to ensure food security for its enormously large population (17 percent of the global population) from only 2.4% area. Development of land use plans for sustainable crop production is a challenging task before the researchers, planners and policy makers under conditions of rising threats of land degradation, soil fertility decline and climatic aberrations. Most of the farmers in India belong to marginal and small land holding categories, which is major cause for concern to produce high yield. However, in the study area majority of the land holdings belong to semi-medium (2-4 ha) and medium (4-10 ha) category, which constitutes 34.91 and 31.98%, respectively (Agriculture census, 2010-11). Under such background a scientific attempt was made in Chhata tehsil of Mathura district, Uttar Pradesh, India to evaluate the land resources for land use planning towards sustainable crop production.

Materials and Methods

Chhata tehsil of Mathura district, Uttar Pradesh, India is situated between 27^{o} 33' to 27^{o} 56' N latitude and 77^{o} 17' to 77 ^{o} 42' E longitudes (Fig.1) and occupies an area of 1063.5 km^{2} with a population of 569021 (The Census of India, 2011). Climate of the area is semi-arid type with distinct hot dry summer and very cold winter. The annual average rainfall and temperature are 558 mm and 26^{o}C, respectively.

The area falls under Yamuna River alluvium, composed of unconsolidated beds of sand, silt and clay as well as their mixture in varying proportions while, very small portion as hillock of Aravalli Mountains. Soils of the study area were evaluated for land capability

(FAO, 1976) and land irrigability classes (All India Soil and Land Use Survey Organization, 1970). Soils were low in organic carbon (< 0.4 %) and available phosphorus (< 12.5 kg ha^{-1}) while, low (< 135 kg ha^{-1}) to medium (135-335 kg ha^{-1}) in available potassium.

Household socio-economic survey was carried out in the study area covering 14 villages from 8 soil series using a comprehensive questionnaire cum proforma under stratified random sampling technique. Respondent farmers (n=140) from different land holding categories (marginal, small, medium and large holdings) were surveyed to generate database required for the development of land use plan. The crop yield collected during socio-economic survey was analyzed for average and range (maximum and minimum).

Results and Discussion

Physiography and soils

The study area consists of four physiographic regions (active flood plains, recent alluvial plains, old alluvial plains and Aravalli hills) and 10 physiographic units. Soils of the area belongs to Inceptisols and Entisols orders and occurs on very gently sloping to nearly level meandering plains of old alluvial origin. Nine soil series was reported in the study area viz., Simri, Garhsauli, Tarauli, Chhatikara, Chhata, Ladpur, Neri, Bechhawan Bihari and Barsana (Kumar *et al.*, 2015, 2017).

Land evaluation for land use planning towards sustainable crop production

Land capability classes

Results reveal that soils of study area have four land capability classes (II, III, IV and VII), which further grouped into 8 land capability sub-classes based on the severity of limitations viz., wetness (w), soil rooting zone (s), erosion (e), salinity/alkalinity (n) and topography/slope (t). Potential and constraints analysis of the soils indicated that all soil series are suitable for crop production except Barsana series, which is suitable for silvi-pastoral development because of rockiness (Table1). Land resources were evaluated for land capability classes based on their potentials and constraints to produce crops sustainably or not (FAO, 1976).

Land irrigability classes

Results indicated that soils of Chhata tehsil were grouped into four land irrigability classes and 6 sub-classes based on the degree of soil limitations (soil texture, soil depth and available water holding capacity, infiltration as well as permeability) for sustained use under irrigation.

The potential and constraints of the land irrigability classes indicates that most of the soil series are suitable for irrigated agriculture except Barsana series due to its rocky nature (Table1). The soils were evaluated for their suitability to irrigated agriculture and grouped under different land irrigability class (All India Soil and Land Use Survey Organization, 1970).

Soils *vis-à-vis* crop production

About 8.68% soils of the study area was affected due to salinity (EC >1.6 dSm^{-1}) and 10.84% due to alkalinity (pH 8.5-9.5). While, only 0.25% area of the tehsil have gravelly sandy loam texture (Fig. 2). However, majority of the soils are suitable to moderately suitable, which offers great scope for sustainable crop production and yield. Mahapatra *et al.*, (2010, 2013) also reported similar constraints and potentials of soils during characterization and classification of soil resources of Mathura district for land use planning.

Table.1 Evaluation of land resources, management needs and recommended crops for Chhata tehsil

Land Capability Class/sub-classes	Land Irrigability Class/sub-classes	Constraints	Management needs	Suitable crops
IIIws (Simri)	3ds (Simri)	Problems of light textured soils with salinity/alkalinity. Moderate limitations of drainage and calcareousness.	Land requires field bunding, leveling, addition of organic manures and fertilizers, assured irrigation and cultivation with careful management practices. Potentially suited to irrigated agriculture if proper drainage with good quality water for irrigation is used.	Maize, wheat, mustard and pigeon pea
IIws (Garhsauli)	2ds (Garhsauli)	Problems of light textured soils (sand and loamy sand) and water availability, slight to moderate limitation of drainage.	Needs intensive nutrient and water management for cereal crops production and it is suitable for irrigated agriculture.	Rice, wheat, sugarcane, maize and fodder crops
IIIsw (Neri)	2sd (Tarauli and Neri)	Problems of light textured soils, water availability and salinity/alkalinity, slight to moderate limitation of drainage.	Needs intensive nutrient and water management beside adoption of recommended management practices for cereal crops production and it is suitable for irrigated agriculture.	Rice, maize, wheat, mustard, sugarcane and pigeon pea
IIIs (Tarauli)	2sd (Tarauli and Neri)	Moderate limitation of soil texture and salinity/alkalinity, moderately slow permeability and nutrient reserve, slight to moderate limitation of soil drainage.	Potentially suited for sustainable crop production if improved management practices such as addition of organic manures, proper dose of fertilizers and it is suitable for irrigated agriculture.	Rice, wheat, mustard, sugarcane, pearl millet and sorghum
IIse (Chhatikara and Chhata)	2s (Chhata and Chhatikara)	Slight limitation of erosion, texture, nutrient reserves and moderate/ rapid permeability, slight to moderate limitation of soil texture and drainage.	Potentially suited for sustainable crop production under improved management practices such as addition of organic manures, optimum doses of fertilizers and land leveling. Suitable for irrigated agriculture.	Rice, wheat, mustard, sugarcane, cotton, pearl millet, sorghum and pigeon pea
IIc (Ladpur)	1 (Ladpur)	Poor drainage, water logging in rainy season, susceptible to seasonal flooding.	Balanced application of inputs (fertilizers and manures), provision for drainage along with improved management practices need to be adopted for better crop production. Suitable for irrigated farming.	Rice, wheat, mustard, sugarcane, maize, sorghum, pearl millet
IVse (Bechhawan Bihari)	3sd (Bechhawan Bihari)	Severe limitations of soil erosion, rapid to very rapid permeability, low to very low water holding capacity and loss of nutrients through leaching. Moderate limitations of soil texture and salinity.	Great potential for crop production if proper soil and water conservation measures are adopted viz., construction of dams and field bunding. Suitable for irrigated agriculture.	Rice, wheat, mustard, pearl millet and vegetables
VIIest (Barsana)	4st (Barsana)	Steep hill slopes with severe problems of gravelly texture, erosion, excessively drained and not suitable for irrigation.	Suitable for silvi-pasture and plantation under proper soil and water conservation. Not suitable for irrigated agriculture.	Silvi-pastoral crops

Parenthesis contained soil series

Table.2 Existing cropping patterns/systems in different soil series of Chhata tehsil

Series	Existing cropping patterns/ systems	
	Kharif	***Rabi***
Simri	Rice, sorghum, green gram, black gram	Wheat, mustard
Garhsauli	Rice, sorghum	Wheat, berseem
Tarauli	Rice, sorghum, pearl millet	Wheat, mustard
Neri	Sorghum, pearl millet	Wheat, sugarcane
Chhatikara	Pearl millet, sorghum	Wheat, mustard
Chhata	Rice, sorghum, cotton, sesamum, cluster bean, pigeon pea and sesbania	Wheat, mustard, berseem
Bechhawan Bihari	Rice, pearl millet	Wheat, mustard
Ladpur	Rice, sorghum, pearl millet and pigeon pea	Wheat, mustard

Table.3 Land use plan for Chhata tehsil towards higher crop yield under different soil series and land holdings

Landholding category	**Crops of different soil series producing high yield (q/ha)**	
	Crop	
	Kharif	***Rabi***
Marginal and Small	Rice (Garhsauli, Neri, Ladpur)	Wheat (Ladpur)
	Pearl millet (Simri)	Mustard (Simri)
	Cotton (Simri)	Sugarcane (Garhsauli)
	Sorghum (Ladpur)	
Medium	Rice (Garhsauli, Neri, Ladpur)	Wheat (Bechhawan Bihari)
	Pearl millet (Simri)	Mustard (Simri)
	Cotton (Simri)	Sugarcane (Chhata)
	Sorghum (Ladpur)	
Large	Rice (Garhsauli, Neri, Ladpur)	Wheat (Bechhawan Bihari)
	Pearl millet (Simri)	Mustard (Simri)
	Cotton (Simri)	Sugarcane (Simri)
	Sorghum (Ladpur)	

Parenthesis indicated soil series with highest crop yield

Fig.1 Location map of observation sites in Chhata Tehsil

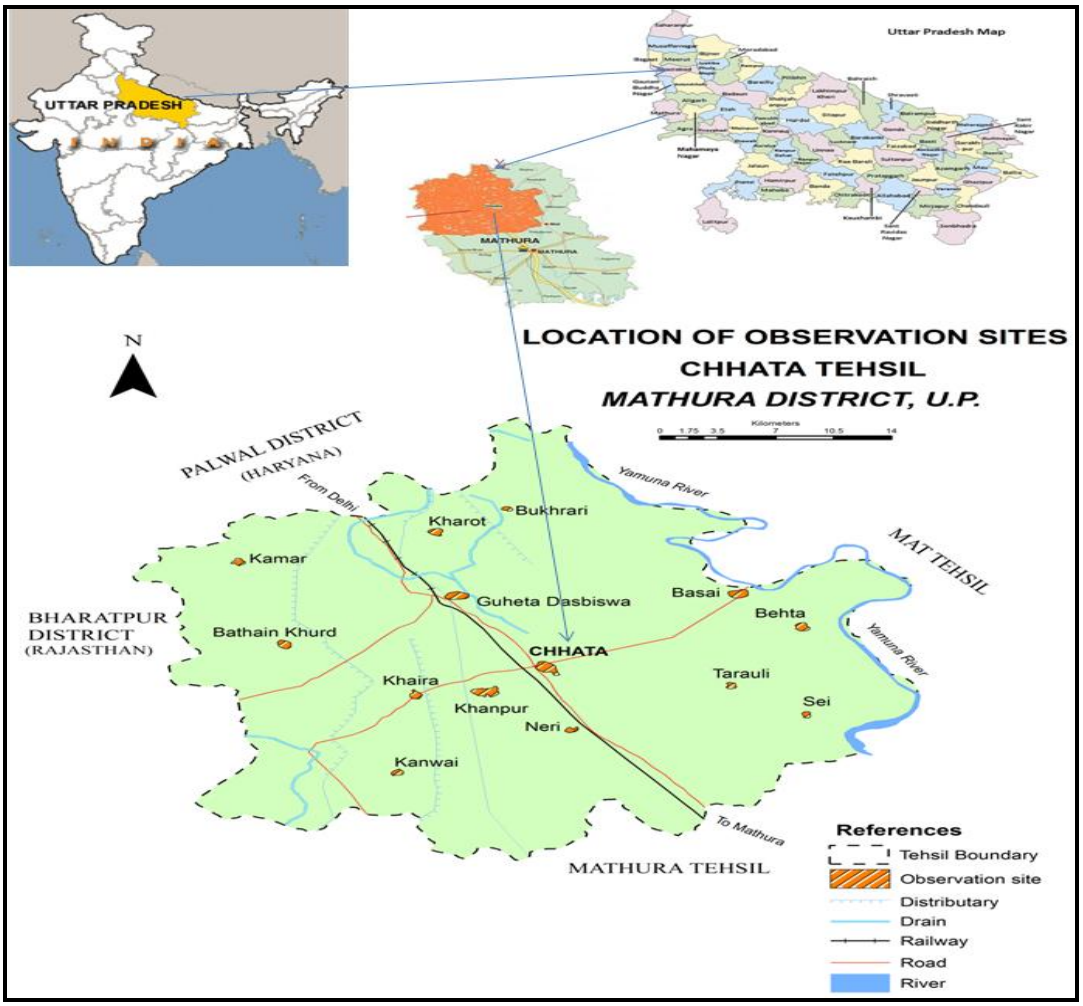
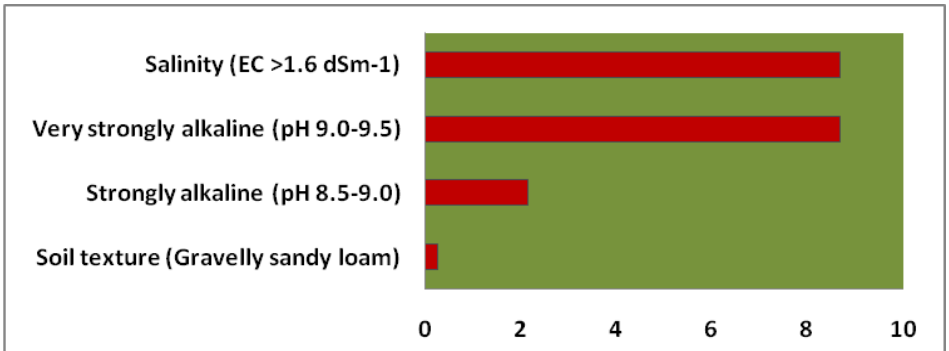


Fig.2 Area affected due to soils related constraints in Chhata Tehsil



	Soil texture (Gravelly sandy loam)	Strongly alkaline (pH 8.5-9.0)	Very strongly alkaline (pH 9.0-9.5)	Salinity (EC >1.6 dSm-1)
Area (%)	0.25	2.16	8.68	8.68

Fig.3 Area under different cropping pattern in Chhata Tehsil

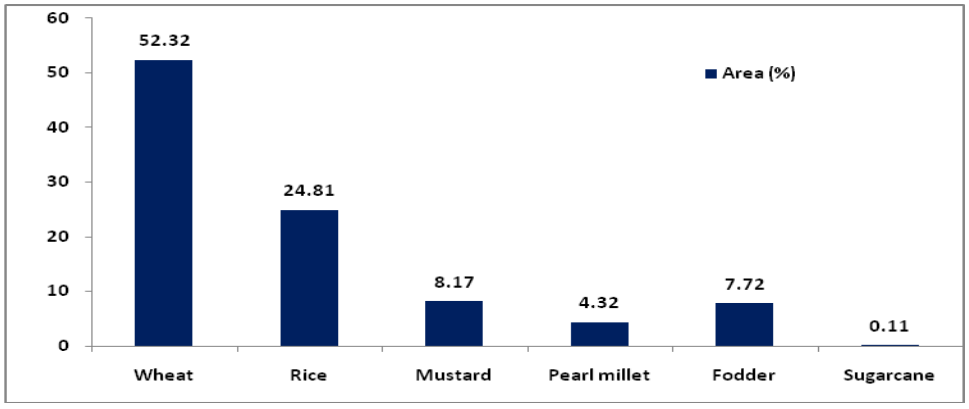


Fig.4 Rice yield under different landholdings and soil series of Chhata Tehsil

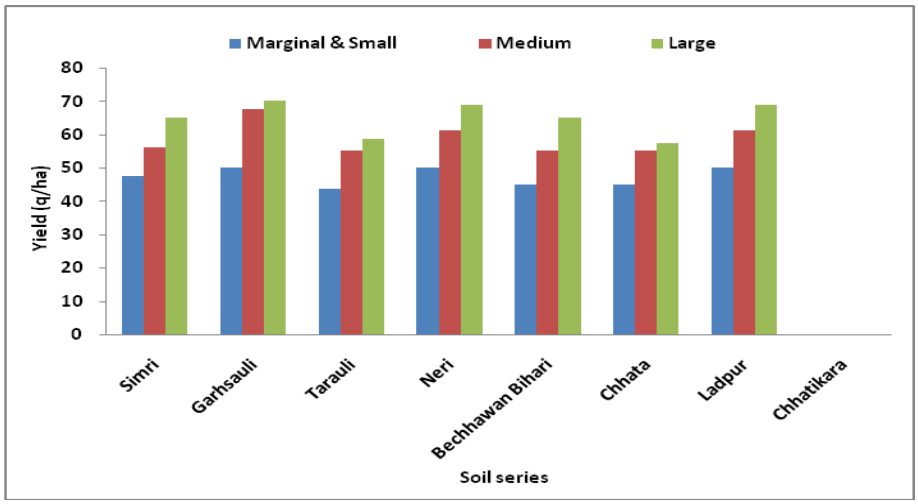


Fig.5 Wheat yield under different landholdings and soil series of Chhata Tehsil

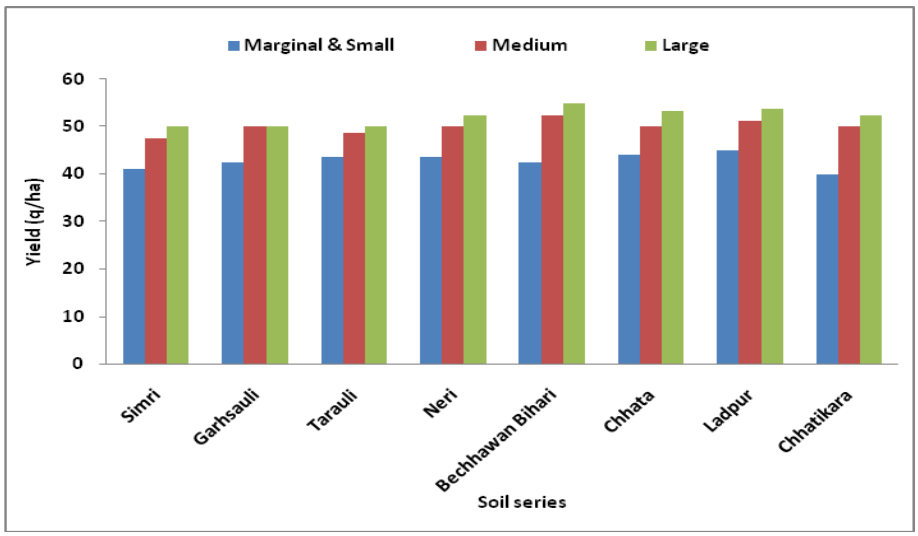


Fig.6 Mustard yield under different landholdings and soil series of Chhata Tehsil

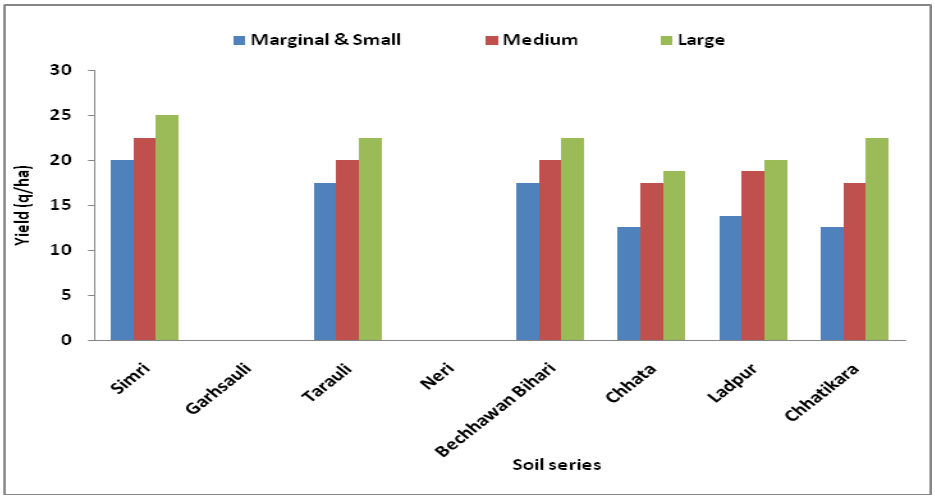


Fig.7 Pearl millet yield under different landholdings and soil series of Chhata Tehsil

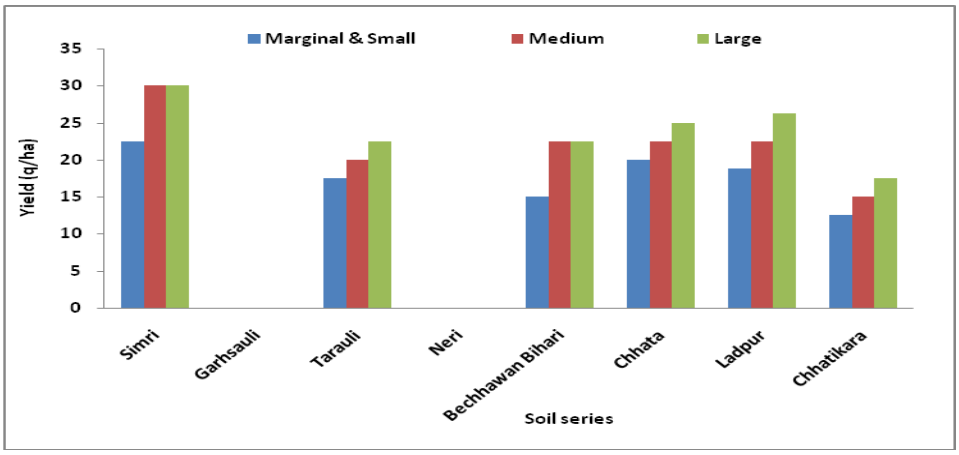


Fig.8 Sugarcane yield under different landholdings and soil series of Chhata Tehsil

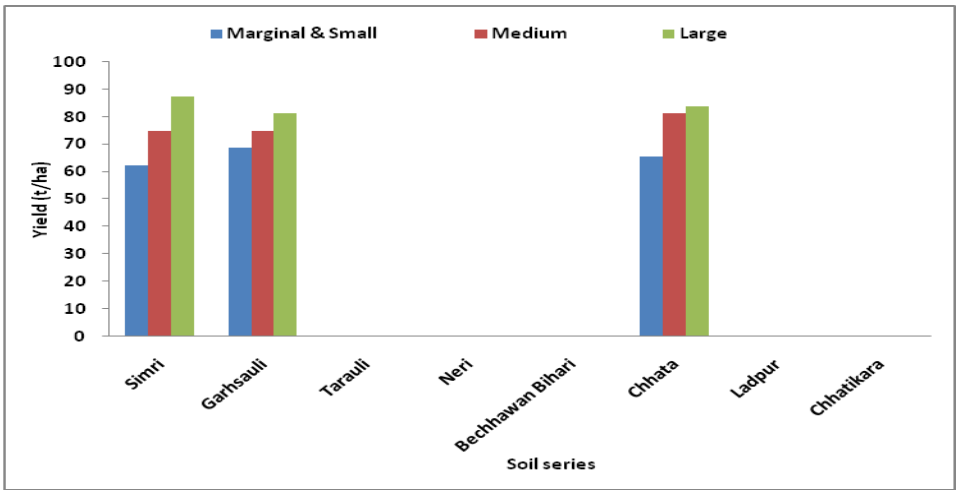
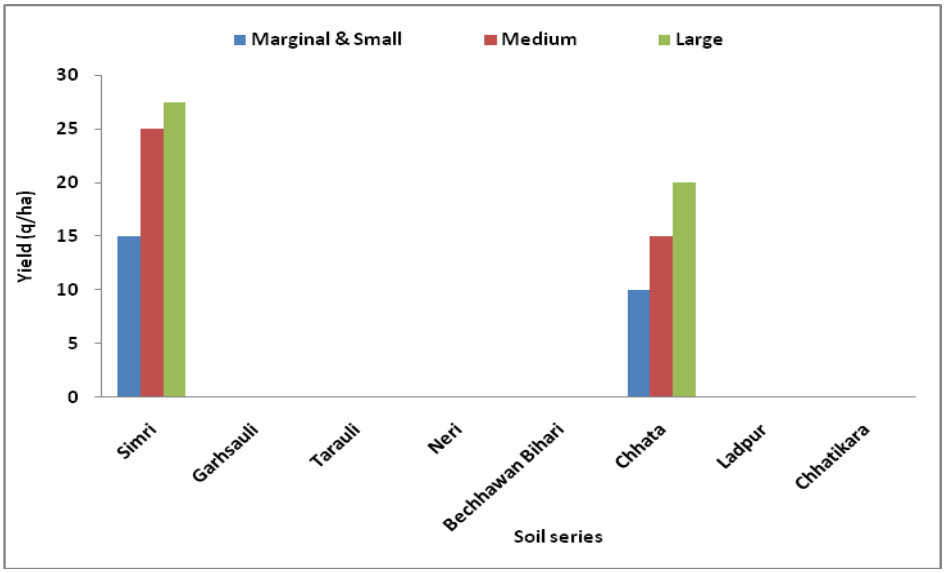


Fig.9 Cotton yield under different landholdings and soil series of Chhata Tehsil



Evaluation of crops for sustainable crop production

Appraisal of crops and cropping patterns

The results of socio-economic survey (respondent farmers) reveal that the area suitable for growing cereals, pulses, oilseeds and fodder crops during 1970s but later on (1990s) rice-wheat system got popularity mainly due to availability of high yielding varieties, irrigation facilities and other inputs. The change in cropping pattern was largely due to change in food habits, high yield from few crops, replacement of pulses and cereals with cash crops, availability and support price for few crops. The existing crops and cropping pattern suggested that soils are suitable for growing several crops such as rice, wheat, sugarcane and cotton in irrigated ecosystems while, mustard, sorghum, pearl millet, pigeon pea and cluster bean in rainfed areas (Table 2). Among the crops wheat occupied highest area followed by rice, which indicated the dominance of rice-wheat cropping system (Fig. 3). Semwal *et al.*, (2001) reported that change in cropping pattern largely attributed to change in food habits, loss of natural resources, low productivity and replacement of traditional cropping system.

Assessment of yield under different land holdings

Crop yield data recorded from the respondent farmers of different land holding categories revealed that average yield was high under large land holdings among and across the soil series (Figs.4-9). Lower crop yield was recorded under marginal and small land holdings while higher yield under large categories. Among the land holdings, variation in crop yield was largely due to difference in input use, engagement of farmers in other subsidiary occupations and under utilization of productive potential of soils etc. However, some crops were grown in few soil series only viz., cotton (Simri, Chhata), Sugarcane (Simri, Garhsauli, Chhata). High yield of crops (average of all land holdings) were observed (Table 3) in Garhsauli series (rice), Ladpur series (wheat), Simri series (mustard, pearl millet and cotton), Chhata (sugarcane) and Ladpur series (sorghum). Higher crop yield under a

particular soil series was attributed to soil suitability, land capability and availability of assured irrigation with good quality water, adoption of improved package of practices and provision for adequate drainage (Kumar *et al.,* 2017).

Land use plan for different soil series and land holding categories

Land use plan was developed for Chhata tehsil towards sustainable crop production under different soil series and land holdings (based on highest yield recorded under a soil series and land holding category). The land use plan for Garhsauli and Simri soil series includes rice and pearl millet during *Kharif* season while, mustard during *rabi* season for Simri series for all land holdings (Table 3). High crop yield recorded under a soil series indicated good soil health, land features, better irrigation facility, socio-economic status and landholding category of the farmers (input use capacity). Das *et al.,* (2006) also reported soil and land features, socio-economic and land holdings as the essential component for land use planning.

Land is essential for survival and growth of living being besides its role in food security, growth and development of a nation. Currently, land is being affected due to land degradation mainly because of non-scientific land use practices, which poses severe threat to its sustenance in many parts of the world including India. Land degradation and other land related issues calls for proper land evaluation and land use planning. The land evaluation in terms of land capability, land irrigability, soil suitability is a useful tool for land use planning because it addresses several soil and land health related issues (salinity, alkalinity, waterlogging and erosion) besides helping in selection of crops and cropping patterns for higher agricultural production. It can be concluded that the land use planning is need of the hour for India to ensure sustainable crop production and food security under the changing socio-economic regime of the marginal and small farming households.

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