Biological Forum – An International Journal **13(2): 282-292(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Management of Natural Resources in Indo-Gangetic Plain Region of India for Sustainable Agricultural Land Use Planning - A Case Study

Ashok Kumar[1*], Sandeep Kumar Lal[2] and R.S. Meena[3]
[1]ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Regional Centre, Delhi, IARI Campus, New Delhi 110012, India.
[2]ICAR-Indian Agricultural Research Institute (IARI), New Delhi 110012, India.
[3]ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Regional Centre, Udaipur-313001, (Rajasthan) India.

(Corresponding author: Ashok Kumar)*
(Received 22 March 2021, Accepted 25 May, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Household socio-economic survey was carried out in fourteen villages of different soil series following stratified random sampling technique. The information on various aspects for land use planning was collected from landholders and landless category respondents (N=140). The study area was delineated into nine soil series, and most of the soils belonging to sandy loam texture. Rice-wheat cropping system was followed in all villages, except Sei. Canal and tubewells comprised major sources of irrigation for 43.8 percent respondents whereas, mean across villages revealed that cattleshed and tubewells were major physical and mechanical facilities available with 50.2 and 43.7% respondents, respectively for the management of livestock and land resources. Among the scientific interventions, timely water availability was crucial to improve the crops yield for 50% respondents. In the study, a model was developed for delineation of alternate land use options and optimal natural resources management as well as their utilization by improving land productivity, yield sustainability and economic viability so as to ensure sustainable agricultural land use planning.

Keywords: Agricultural land use planning; IGP; Management; Natural resources; Productivity; Sustainable

INTRODUCTION

Declining natural resources *viz.,* land, water and vegetation in the past few decades is a cause of concern for policy planners across the world. Besides, the sustainability of these resources is threatened due to indiscriminate uses. Anthropogenic activities are the major drivers of global land use changes (Wheater and Evans, 2009). Further, changing land use and management practices are responsible for soil erosion and in turn led to irrevocable land degradation, which affects 23.5% of the earth's land area globally (Lal, 2010; Guo *et al.,* 2019). Amongst the natural resources, soil and land resources are vital for survival of any civilization and economic prosperity of the nations. In the past few decades, India has witnessed a sharp decline in the availability of per capita cultivable land, thereby increasing marginal and small landholdings. Declining landholding size may not be able to meet the food demand of the burgeoning population in India. As a result, majority of the farmers (86.2 percent) in India comes under marginal and small landholding categories (Agriculture Census, 2015-16).

Water is equally important for the survival and existence of all life, and considered as a basic resources required for food, feed, fuel, and fiber (Kumawat *et al.,* 2020). Globally, irrigated agriculture is the largest consumer of water resources (Portmann *et al.,* 2010; Brauman *et al.,* 2013) and the demand for water in agriculture will continue to increase further (Kanwar, 2010; Neumann *et al.,* 2011). Thus, agricultural production in irrigated regions is becoming more water-constrained (Qureshi and Neibling, 2009). Therefore, concerted efforts are required to conserve and utilize the water resources judiciously for sustainable agricultural production. However, Indian agriculture is facing resource degradation problems largely due to increasing water demand and consumption, and more and more use of chemical fertilizers to fetch higher crop yields (Abrol *et al.,* 2012; Khan and Hanjra, 2009; Rodell *et al.,* 2009; Sehgal and Abrol, 1994; Singh, 2000). Under such conditions, land based solutions take into account the relevant bio-physical, environmental, socio-economic and institutional factors (Dumanski and Craswell, 1998; Mennis and Hultgren, 2006; Ochola and Kerkides, 2004) due to their pivotal role in managing the natural resources as well as sustaining agriculture.

Indo-Gangetic Plain (IGP) region of India is very diverse in natural resources, and thus offers great scope to support multiple livelihood activities. IGP is one of the most extensively fertile and densely populated alluvial plain regions in the world. It accounts for 50% of the total food grain production and capable of feeding 40% population of the country (Pal *et al.,* 2009). Based on physiography and bio-climate, it is sub-divided into Trans Indo-Gangetic Plains (TIGP), Upper Indo-Gangetic Plains (UIGP), Middle Indo-Gangetic Plains (MIGP) and Lower Indo-Gangetic Plains (LIGP) (Narang and Virmani, 2001). The study area, *Chhata tehsil* in Mathura District of Uttar Pradesh belongs to UIGP region where agriculture faces several constraints including salinity/sodicity, and low rainfall. The livelihood in this area is largely depends on agriculture and livestock. Agriculture is mainly dominated by cereals, especially rice and wheat although other crops, including the vegetables and fruits are also grown. In the UIGP region, agriculture and livestock based land uses have medium current utilization as well as potential for improvement of natural resources whereas, forestry and fisheries have low utilization but high to medium potential (Patil *et al.,* 2014). Inappropriate cropping patterns have created unprecedented problems for the existing ecosystems. Thus, protection of natural resources and ecosystems needs immediate attention to promote sustainable and productive land use systems. The productivity and land use efficiency of an area reflects the extent and degree of utilization of natural resources in agriculture (Mukhopadhyay *et al*., 2004). Hence, urgent attention is required to establish the balance in potential use of natural resources, selection of suitable crops, judicious use of agricultural inputs and effective management practices for developing an optimum land use plan (Chattopadhyay, 1997). Land use planning at various scales including the local level planning (village) is very relevant for natural resource bases (land, livestock and forest) appraisal and their improved utilization for augmenting higher agricultural productivity and sustainability. As the resource base of village plays crucial role in creating material conditions for collective actions (Ray, 2008). Therefore, land use planning technology holds immense potential to address the issues of food and livelihood security besides serving as a future guiding tool to policy planners and researchers for ensuring sustainable agricultural land use planning.

MATERIAL AND METHODS

A. Profile of the study area

The study was carried out in *Chhata tehsil* of Mathura District, Uttar Pradesh, India, which comes under UIGP region of the IGP of India and is located between 27^o 33' to 27^o 56' N latitudes and 77^o 17' to 77^o 42' E longitudes. It is bounded by Faridabad District of Haryana in the north, River Yamuna in the east, tehsil Mathura in the south and District Bharatpur of Rajasthan in the west. It occupies a total area of 1063.5 km^2 and supports total population of 569021 (The Census of India, 2011). The soils of this area mainly belong to *Inceptisols* and *Entisols* orders, and majority of them occur on very gently sloping to nearly level meandering plains of old alluvial origin. The climate is semi arid, which is characterized by hot dry summers and very cold winters. The mean minimum, maximum and annual temperature is 14.37, 37.15 and 25.73°C, respectively while average annual rainfall is 655.5 mm, most (about 80-85%) of which is received during the rainy season (June to September).

B. Survey methodology

The study area was delineated into nine soil series *viz., Simri, Garhsauli, Tarauli, Neri. Chhatikara, Chhata, Bechhawan Bihari, Ladpur and Barsana.* All the soil series are suitable for agriculture, except Barsana series due to its rocky nature (part of Aravalli hills). Therefore, the household socio-economic survey was carried out in the agriculturally suitable soil series covering 14 villages. The socio-economic data were collected in a comprehensive questionnaire cum proforma, following stratified random sampling technique of data collection. The respondents interviewed/surveyed (N=140) during the socio-economic survey included farmers (marginal, small, medium and large land holding category) and randomly selected landless labourers, agricultural labourers and daily paid workers.

C. Sustainable Agricultural Land use planning

The evaluation and integration of natural bio-physical as well as socio-economic resources, and application of economic and sustainability indices were done to delineate alternate land use options, and in turn to ensure optimal natural resources management for sustainable agricultural land use planning.

D. Statistical analysis

The survey data were processed using Microsoft excel software for descriptive statistics (mean, percentage, standard deviation and range). The datasets were interpreted for optimum resource management to ensure sustainable agricultural land use planning of the study area.

RESULTS AND DISCUSSION

A. Natural soil site conditions

In the study area, 4 major physiographic regions *viz.,* active flood plains, recent alluvial plains, old alluvial plains and Aravalli hills have been identified (Table 1). Geology is mainly recent to old alluvium transported by river Yamuna and its tributaries, except Aravalli hillocks having mixed geology. The study site mainly comes under Yamuna river alluvium and conformable series of fluvial and alluvial deposits and hillocks of Aravalli in some areas. General elevation of the area is 185 meter (m) above mean sea level (MSL) except higher elevations of about 220-240 m above MSL at some hillocks. Most of the study area belong to very gentle (1-3%) to gentle slopes (3-5%), except hillocks where slope ranges from gently to moderately steep (8-15%) to steeply sloping (15-30%). Sandy loam is dominant textural class, and most of the soils are subjected to slight to moderate erosion, except severe erosion problem in hillocks. The climate is favourable to support variety of land use land cover (LULC), including agriculture, horticulture, agro-forestry, and several other natural vegetations. The occurrence of soil salinity and sodicity was quite perceptible in the area. Patil *et al.* (2014) reported that majority of the soils in the UIGP are sandy loam and having problem of soil sodicity.

Uttar Pradesh alone has 1.37 M ha salt-affected soils in the country (Mandal *et al.*, 2018). However, area under saline and sodic soils in the IGP region of India is 0.56 and 1.79 M ha area, respectively (Arora and Sharma, 2017). LULC in the area consisted of agriculture, horticulture, livestock, agro-forestry and other natural vegetation (integral part of land uses and livelihood security). Dadhwal *et al.* (1995) also recommended agri-horticulture and agri-horti-silviculture systems along with livestock component for North-Western plains of Uttar Pradesh.

B. Natural vegetation

Natural vegetation in the area is of deciduous and evergreen type. Dominant tree species are Bilayati Babul (*Leucaena* sp.), Subabool (*Acacia nilotica),* Neem (*Azadirachta indica* L.), Shisham (*Dalbergia sissoo*), Ber (*Zizyphus jujube)*, Pipal (*Ficus religiosa).* Verma *et al.* (2017) also reported dominance of these tree species in most of the districts of Uttar Pradesh. Besides, some species of weeds, grasses and shrubs were also recorded which included Cyprus (*Cyprus* spp.), Doob grass (*Cynodon dactylon)*, Munj (*Saccharum munja)* and Jharberi (*Zizyphus numularia)* (Table 2).

Table 1: Natural soil-site conditions of the study area.

Natural resources		Characteristic features			
a. Physiography		**Active flood plains**	**Recent alluvial plains**	**Old alluvial plains**	**Aravalli hills**
Area	(ha)	5667	26866	72589	435
	(%)	5.4	34.5	68.8	0.4
i) Soils		Mostly sandy soils, slightly alkaline, subjected to annual flood	Loamy sand, sandy loam to loam, slight to moderately alkaline, occasional flood	Sandy loam to loam with patches of loamy sand and clay loam. Slight to moderate saline/ & alkaline	Gravelly sandy loam, neutral soil reaction
ii) Slope		Nearly level to gently sloping	Nearly level to gently sloping	Nearly level to gently sloping	Gently to moderately steep to steeply sloping
iii) Erosion		Slight to moderate	Slight to moderate	Slight	Moderate to severe
b. Geology		Recent to old alluvium in nature, transported by Yamuna River and its tributaries			
c. Climate		Semi arid, characterized by a hot dry summer and very cold winter			
d. Land use land cover		Agriculture, Horticulture, Agro-forestry, and other natural vegetation, and livestock			

Table 2: Dominant species of different natural vegetation in the study area.

Type of vegetation	Common name	Botanical name	Uses/Significance	Availability
Tree	Bilayati babool	*Leucaena* sp.	Fuel wood, furniture	Moderate
	Babool	*Acacia nilotica*	Fuel wood, furniture	Moderate
	Neem	*Azadirachta indica* L.	Furniture, shade tree	Moderate
	Shisham	*Dalbergia sissoo*	Furniture, shade tree	Moderate
	Ber	*Zizyphus jujuba*	Commercial, edible	
	Pipal	*Ficus religiosa*	Religious	Moderate
Grass	Doob grass	*Cynodon dactylon*	Animal grazing during fodder scarcity, used as lawn grass	Abundantly
Weed	Cyprus	*Cyprus rotundus*	Problematic weed	Sparse
	Munj	*Saccharum munja*	Rope making	Sparse
Shrubs	Jharberi	*Zizyphus numularia*	Act as fodder during scarcity	Sparse

Fortunately, most of the species were found to occur in the problematic areas such as salt affected and waterlogged lands (Fig. 1), though their presence was also observed in normal cultivated lands. Such natural vegetation reflected diversified land uses *viz.*, silviculture, silvi-pasture and silvi-horticulture, and provide ample scope for productivity improvement of some problematic areas. Rai *et al.* (2001) reported beneficial effects of silvo-pastoral systems for improving degraded lands in the semi-arid regions of Uttar Pradesh.

C. Land use and cropping pattern

Land use statistics revealed that among the surveyed villages of *Chhata tehsil*, maximum forest area was reported to be in the Kamar while, negligible area in the Kharot, Neri and Basai while, no forest area in the remaining villages. Patil *et al.* (2014) also reported negligible forest area in the IGP region of India.

Barren and uncultivated land was highest in Tarauli whereas, culturable wastelands, fallow land as well as both net sown and irrigated area were reported to be highest in Sei village. Highest un-irrigated area was recorded in Behta (400.5 ha) and Husaini (268.1 ha) village (Table 3). The barren and uncultivated land offers great scope for additional land for cultivation through reclamation efforts. Khan *et al.* (2013) also held similar views that additional land under cultivation could be brought by reclaiming the barren and uncultivated lands. Problematic lands (salt affected and waterlogged) in the area were largely under *Subabul*, *Babul* and *Sachharum species*, which provide shield against soil erosion and fodder availability for animals at the time of scarcity (Fig. 1). Verma *et al.* (2017) also reported suitability of *Subabul*, *Casuarina* and *Babul* for afforestation on deficient soils. They further reported that reclamation of sodic soils can be possible by growing plants on the degraded sites.

Farm forestry *i.e.*, growing of woody perennials and fruit trees on the farm bunds with the intention to meet the timber need, income generation and to avail ecosystem services is very common the area (Fig. 2). Studies indicated that cultivation of trees on farmlands along with agricultural crops helps to generate supplementary income (Scherr, 2004; Sharma *et al.*, 2009).

Table 3: Land use in the surveyed villages of study area (Census of India, 2011).

Village	Area (ha)						
	Forests	**Barren and un-cultivable land**	**Culturable waste land**	**Fallow land**	**Net area sown**	**Total irrigated land**	**Total un-irrigated land**
Bathain Khurd	0.0	0.9	0.0	16.3	835.6	835.6	0.0
Kamar	36.6	63.0	0.0	76.5	1105.8	1012.6	93.2
Guheta Das Biswa	0.0	1.2	0.0	3.8	456.7	456.7	0.0
Bukhrari	0.0	5.3	1.9	32.8	825.5	825.5	0.0
Tarauli	0.0	73.1	1.5	1.9	854.6	854.6	0.0
Kharot	4.5	6.6	25.0	118.9	1113.2	1113.2	0.0
Neri	0.2	0.0	0.5	41.2	721.5	721.5	0.0
Husaini	0.0	0.0	5.6	1.3	669.1	401.0	268.1
Basai	0.2	51.0	3.5	9.9	375.3	372.2	3.1
Behta	0.0	0.0	1.6	2.7	906.0	505.4	400.5
Sei	0.0	45.6	69.0	129.9	1505.9	1505.9	0.0
Khanpur	0.0	0.0	0.7	1.1	411.1	411.6	0.0
Kanwai	0.0	0.0	5.5	34.8	1505.7	1475.0	30.6
Khaira	0.0	1.1	41.9	86.7	1440.7	1437.2	3.5
Mean	3.0	17.7	11.2	39.8	909.1	852.0	57.1
Range	0-36.6	0-73.1	0-69.0	1.1-129.9	375.3-1505.9	372.2-1505.9	0-400.5
SD	9.8	27.3	20.5	45.2	384.4	409.0	122.9

Fig. 1. Pictures of *wastelands* due to salinity/sodicity and waterlogging of the study area.

During the socio-economic survey, the respondent farmers revealed that nearly four decades ago land use in the study area consisted of cereals, pulses, oilseeds, sugar crops, fibres, fruits and vegetables. But in due course of time, a paradigm shift occurred towards rice-wheat cropping system and few cash crops only. This shift in cropping pattern was largely ascribed to assured prices and market availability, high yield and profits, and food habits. Though, rice and wheat being dominant crops in the area but other crops *viz.*, mustard, potato, sugarcane, pigeon pea, pearl millet and sorghum were also cultivated in the sizeable proportion. Besides, sesame, cluster bean, sesbania and cotton cultivation was also observed, but on limited scale (Table 4). The crops and cropping systems reported in the study is in close agreement to the previous studies carried out in IGP Region of India (Panigrahy *et al.,* 2010; Johansen *et al.*, 2000; Koshal, 2014).

Results indicated maximum variation in the number of crops grown was recorded in Kamar and Bukhrari village (Fig. 3).

Fig. 2. Pictures of *farm forestry* on the bunds alongside agricultural crops.

Table 4: Crops grown in the surveyed villages of the study area.

Village	Crop grown
Bathain Khurd	Rice, wheat, mustard, sorghum
Kamar	Rice, wheat, mustard, sorghum, green gram, lentil, sesame, black gram
Guheta Das Biswa	Rice, wheat, sorghum, barseem
Bukhrari	Rice, wheat
Tarauli	Rice, sorghum, wheat, mustard, pearl millet
Kharot	Rice, wheat, sorghum
Neri	Rice, wheat, sorghum, sugarcane, pearl millet
Husaini	Rice, wheat, sorghum, pearl millet, pigeon pea, mustard
Basai	Rice, wheat, mustard, pearl millet
Behta	Rice, wheat, mustard, pearl millet
Sei	Wheat, pearl millet, mustard, sorghum
Khanpur	Rice, wheat, sorghum, mustard, cotton, berseem
Kanwai	Wheat, mustard, sesame, cluster bean, sorghum, cotton, pigeon pea
Khaira	Rice, wheat, sorghum, mustard, cotton, sesbania

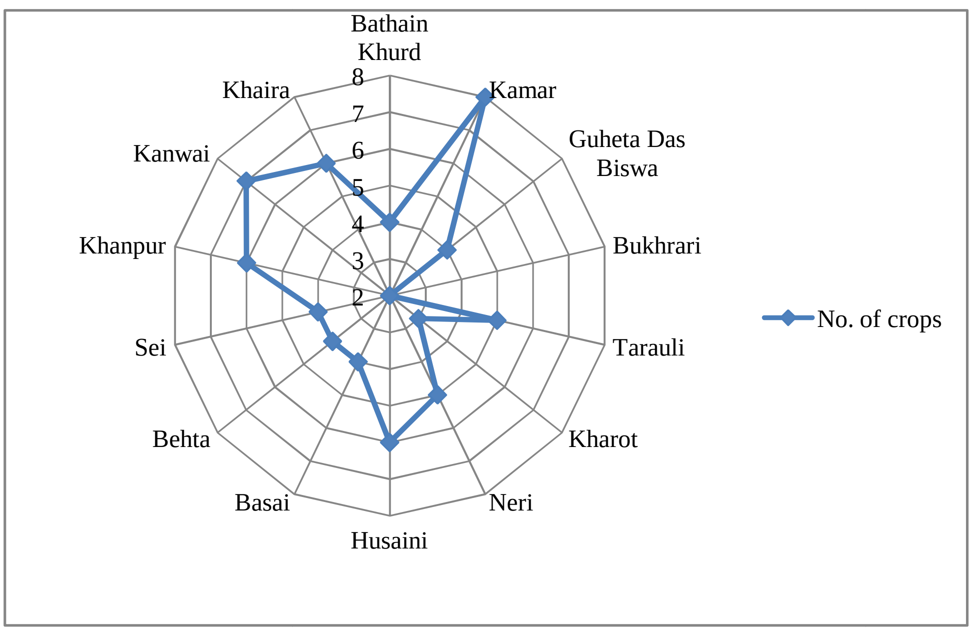

Fig. 3. Variations in the number of crops grown in the surveyed villages of study area.

This variation was ascribed mainly to the variation in soil and land suitability, water availability, market availability and prices, socio-economic and management conditions. Semwal *et al.* (2001) also reported similar factors for change in cropping pattern.

D. Source of irrigation, water table depth and quality

Results revealed that maximum respondents (43.8%) had both canal and tubewell irrigation facility while, 38.4 and 17.8% respondents were dependent on tubewells and canal water, respectively for irrigation (Fig. 4). Both canal and tubewell water application for irrigation indicated conjunctive use of water to ensure optimum soil quality by preventing waterlogging and salinity build up. Srivastava *et al.* (2012) reported similar practices of water usage for irrigation in western IGP (Trans IGP) to thwart the waterlogging and salinity build up. Besides, opinion of the respondents about the water table depth was also recorded during survey, which revealed depth of water table ranging from 1-3 m in the villages of Simri soil series to 20 m in the surveyed sites of Chhatikara soil series. Water quality for drinking as well as irrigation purpose was reported to be good in most of the villages, except in the villages of Simri, Chhatikara and Chhata soil series where the respondents cited quality of water as moderately good to good, and poor to moderately good, respectively (Table 5). Patil *et al.* (2014) also reported poor water quality (mainly alkali water problem) in some of the districts in IGP, including Mathura district of Uttar Pradesh. Besides, growing salinity hazard, lowering water table (overexploitation of groundwater) and decreased soil fertility are other major concerns in IGP.

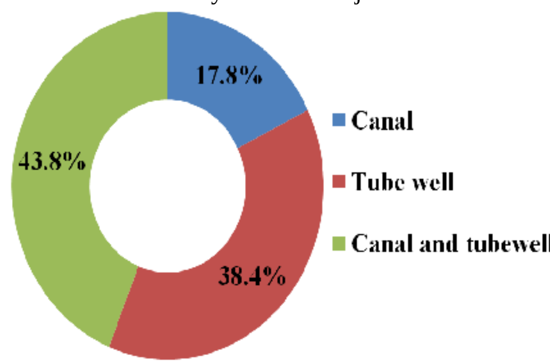

Fig. 4. Percent respondents of the study area having different sources of irrigation.

Table 5: Descriptive statistics of water table depth, and qualitative assessment of water quality in the surveyed villages of different soil series.

Soil series/village	Depth of water table (m)		Water quality#
	Range	Mean	
Simri (Bathain Khurd, Kamar)	1.0-3.0	2.0	Moderately good to good
Garhsauli (Guheta Das Biswa)	8.0-10.0	9.0	Good
Tarauli (Bukhrari, Tarauli)	3.0-10.0	6.5	Good
Neri (Kharot, Neri)	3.0-7.0	5.0	Good
Chhatikara (Sei)	17.0-20.0	18.5	Poor to moderately good
Chhata (Khanpur, Kanwai, Khaira)	1.0-5.0	3.0	Poor to moderately good
Bechhawan Bihari (Behta)	10.0-12.0	11.0	Good
Ladpur (Husaini, Basai)	10.0-15.0	12.5	Good
Range across the series/village	1.0-20.0	-	-

Status is ascribed based on the opinion of respondents

D. Livestock resources

Results revealed that milch buffaloes had more percentage share than milch cows in all the surveyed villages, except Bathain Khurd. In the Kamar village, both non-milch cows and buffaloes had highest share *i.e.,* 41.7 and 37.5%, respectively. Bathain Khurd, Behta and Husaini recorded maximum share of milch cows as well as milch buffaloes (Fig. 5). Koshal (2014) also reported livestock resources of IGP having high population of buffaloes and cows. The information about livestock resources was included in the study, as the livestock are important as an alternative source of income, particularly for marginal and small farmers and landless labourers besides their role in employment generation. Dastagiri (2004) also expressed similar views about income and employment under livestock production system. Besides, Patil *et al.* (2014) reported the importance of livestock resources in the livelihood security of households in the IGP region of India. Further, livestock resources are crucial for poverty alleviation and combating food insecurity as well as malnutrition (Enahoro *et al.,* 2019).

E. Physical and mechanical resources used to manage the natural resources

In the past few decades, importance of natural resources has been realized world over due to their significance in agriculture sustainability and livelihood security. Thus, efficient and effective management of natural resources *viz.,* soil, water, vegetation and livestock animals is on high agenda at every scientific forum due to being important constituents of life supporting system. Therefore, inventorization of physical and mechanical resources available with the respondent households is of immense use due to their role in improving the quality and productivity potential of natural resources. Mechanical resources such as tractor helps in tilling and ploughing of land resources, thereby ensuring their optimum management for improved cultivation.

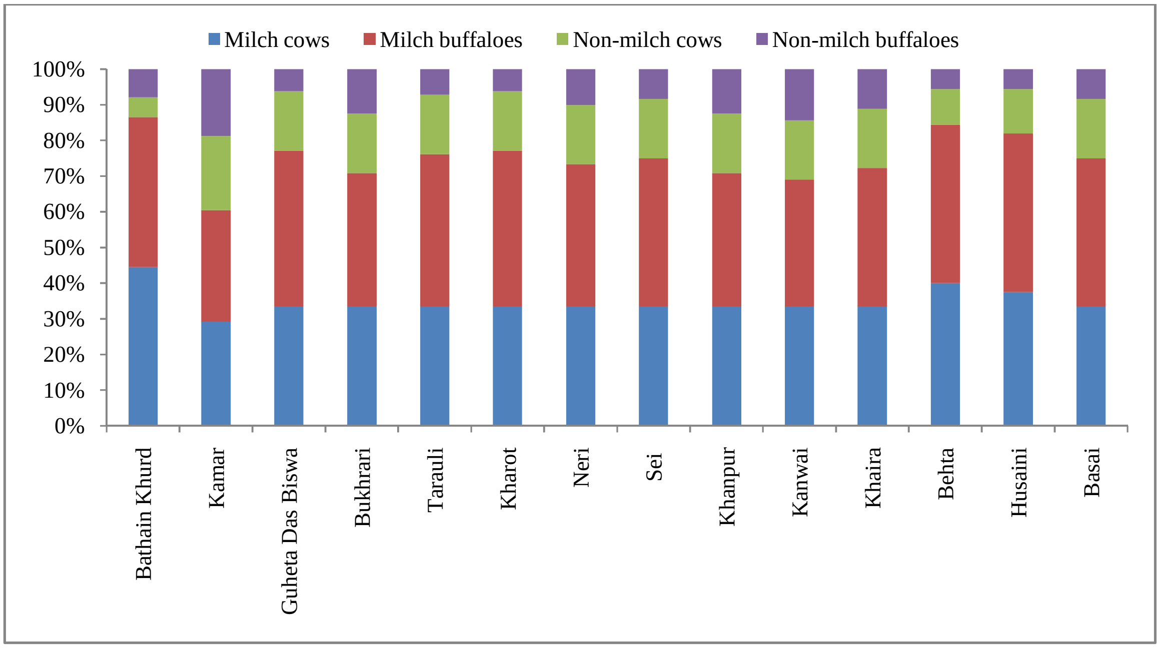

Fig. 5. Livestock resources of the respondent households' of study area.

Tube-wells, diesel and electric pumps ensure water supply for irrigating the crops besides, improving the water use efficiency. Physical resources such as cattle-shed are important for better management of livestock resources and thus, improving their production potential. Therefore, information in this regard was collected during the socio-economic survey, and the results revealed that cent percent surveyed respondents of Kamar village had cattle-shed for their livestock and tubewell for irrigation. Cattle-shed protects the livestock against the vagaries of nature and other threats, besides providing healthy shelter. Electric motor to lift irrigation water was another important mechanical resources found to be highest in Behta (42.9%) and Kharot (37.5%) village. However, diesel pump was most commonly used mechanical device compared to electric motor in majority of the surveyed villages to lift and manage the irrigation water. Highest respondents possessing diesel pump belonged to Kamar (81.8%) and Guheta Das Biswa (62.5%) villages whereas, maximum respondents of Khaira (57.1%) and Kharot (50.0%) village had tractor to till and plough one of the important natural resources *i.e.*, land besides, managing other natural resources (Fig. 6). More respondents had cattle-shed, indicating the prevalence of livestock rearing activities in all the villages. However, means of irrigation and devices such as tubewell, electric motor and diesel pump to lift or pump the water was less due to canal irrigation facility and availability of these resources on hiring basis.

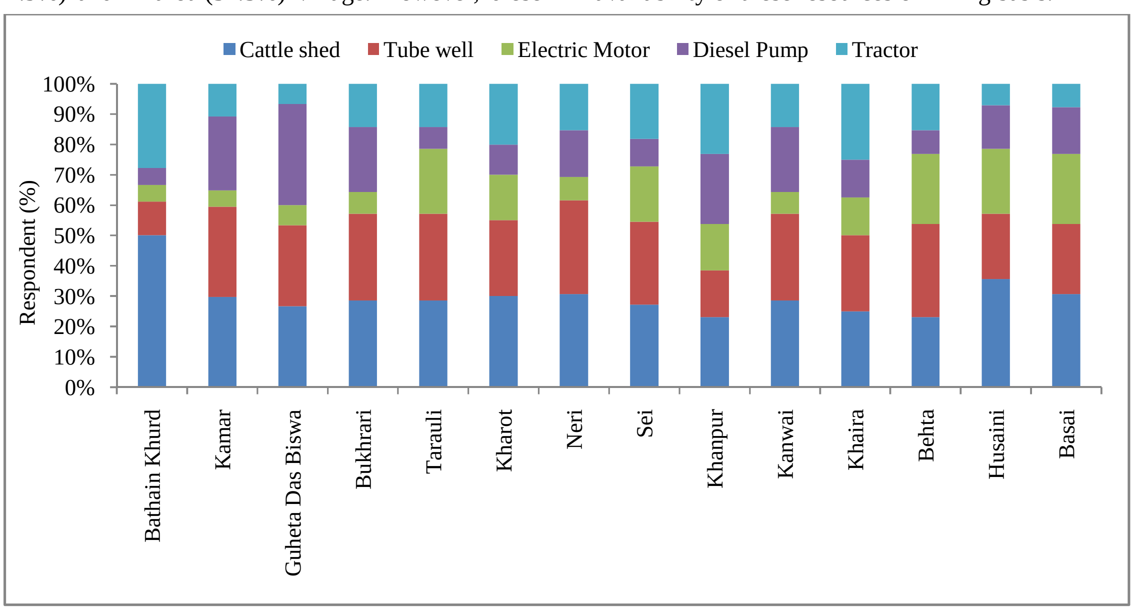

Fig. 6. Respondents' possessing various physical and mechanical facilities for managing natural resources.

However, the tractors were mainly owned by the large landholders and economically well off respondents whereas, marginal and small farmers avail the services on hiring basis. The information about physical and mechanical resources is of immense help in managing the natural resources, besides improving their potential for sustainable production for future. Mehra *et al.* (2017) also considered socio-economic factors, including physical and mechanical resources for managing various natural resources under resource management domain approach study in Mewat Region of Haryana (Trans IGP region). Sarkar (2020) reported the role of access to productive assets and capital such as land and livestock in taking up gainful economic activity.

F. Suggestions to improve the agricultural productivity

Results of the household socio-economic survey revealed that non-availability of irrigation water at appropriate time due to electricity cut and other bottlenecks, and salt affected soils and inadequate drainage were severe constraints to sustainable agriculture production. Keeping these problems in mind, need based suitable scientific interventions for improving the agricultural productivity were suggested during interaction with the respondents. The results revealed that timely availability of water may help in enhancing agricultural productivity significantly, as agreed by majority of the respondents (50%). However, 32.5% respondents expressed their satisfaction over provision for adequate drainage, and about 17.5% respondents conveyed that reclamation of salt affected soils will be an apt strategy to improve the agricultural productivity in the study area (Fig. 7). Similar constraints *viz.*, salt problems, waterlogging and declining water availability for irrigation due to lowering water table depth etc. for sustainable agriculture in the IGP region was also reported by Patil *et al.* (2014).

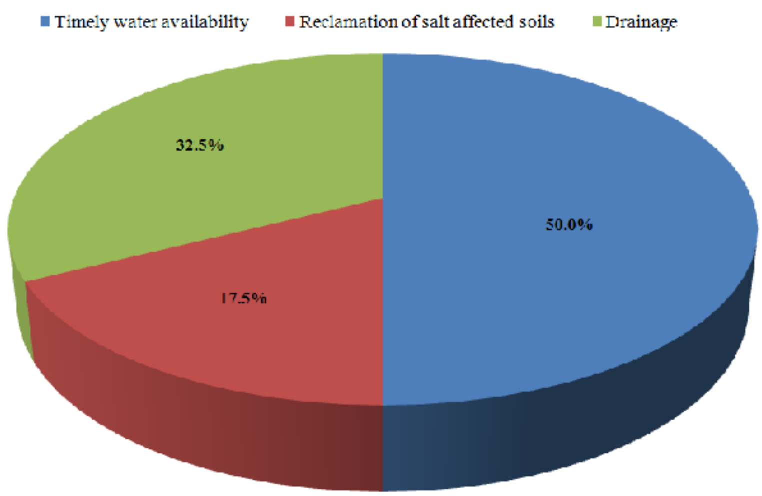

Fig. 7. Proposed scientific interventions for improving crop yield agreed upon by the farmers of the study area.

Suggested model for delineation of alternate land use options and optimal resources management for sustainable agricultural land use planning

The developed model for delineation of alternate land use options and optimal resources management for sustainable agricultural land use planning is based on the state of socio-economic and bio-physical resources of the area, their potential and constraints, and economic and sustainability indices. Thus, the model for sustainable agricultural land use planning takes into account the economic viability, yield sustainability and soil suitability (Fig. 8). The above aspects ultimately affect the livelihood security, as well as food and nutritional security directly or indirectly. Therefore, it is imperative to assess the socio-economic and bio-physical resources for effective management of natural resources. The study location truly represents the UIGP region in terms of soil and natural bio-physical resources. Hence, the methodology and model developed for alternate land use options may be applied under similar soils and bio-physical resources available in the UIGP as well as IGP region of India.

Policy implications of the suggested model

- Bio-physical (soil, climate and vegetation) and socio-economic factors of the area need to be considered before suggesting the land use plan.
- Land/soil resources need to be utilized according to their capability and suitability classes.
- Economic and sustainability aspects of various crops in terms of benefit to cost ratio (B C Ratio) and sustainability yield index (SYI) need to be evaluated for effecting policy formulation pertaining to agricultural development.
- In the agrarian economies, livestock is an important constituent of livelihood security, thus need to be considered while proposing alternate land use options.
- The natural vegetation provides several provisioning services such as timber, feed and pulp besides, some additional income. It also provides ample scope for restoration of degraded lands, conservation and preservation of natural ecosystems, and thus need to be kept at centre

stage while formulating polices for natural resource management and land use policy.

- Agroforestry, particularly the farm forestry offers great scope for employment and income generation for farmers besides, effective utilization of available space. Therefore, policy planning for uplifting the livelihood of poor and marginal sections may exhort upon the farm forestry practices.
- Alternate land use options based on the criteria depicted in the model helps in ensuring food, feed, nutritional and livelihood security. Thus, it may be considered as an important basis for policies directed to achieve food and nutritional security.

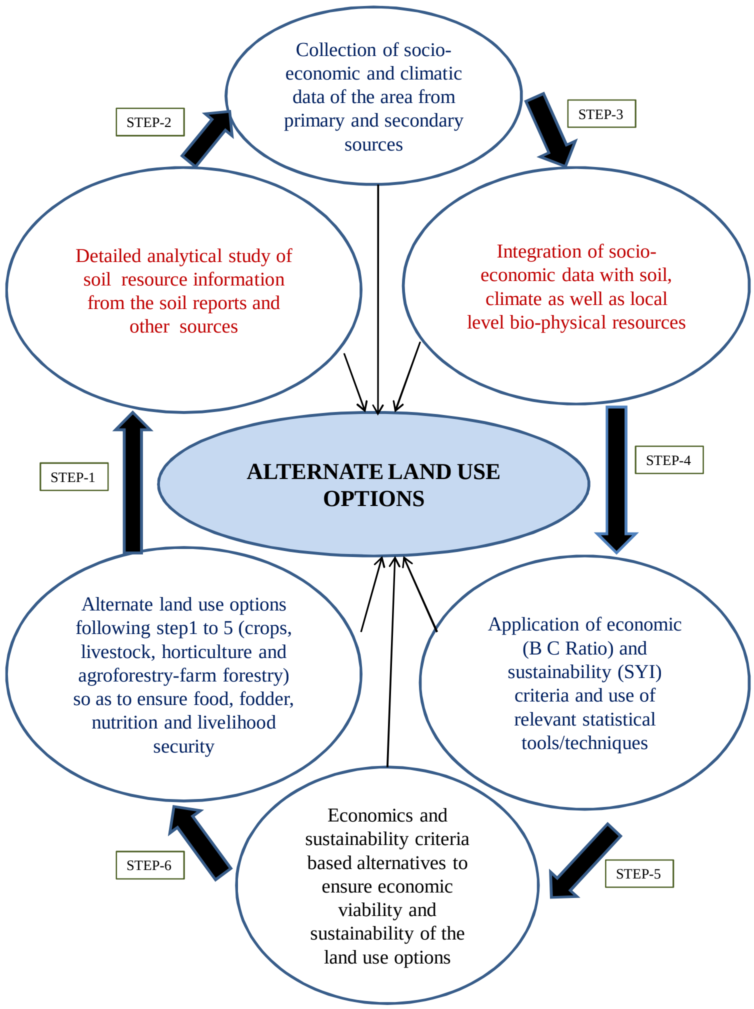

Fig. 8. Suggested model for delineation of alternate land use options and optimal resources management for sustainable agriculture land use planning.

CONCLUSION

Among the natural resources, land and climate are the most important resources for sustenance and survival of other natural resources *viz.*, water, vegetation, and livestock. Further, these two variables govern the agricultural and other land uses in an area thus, need to be considered in land use planning studies. Beside bio-physical resources, socio-economic resources also have greater role to play in allocation and management of different natural resources, including land uses. The study area was delineated into nine soil series for effective utilization and management needs view point. Rice-wheat cropping system occupied maximum area but other crops such as mustard, potato, sugarcane, pigeon pea, pearl millet, sorghum and cotton were also grown successfully. Besides agriculture, livestock is also considered important for livelihood of the respondents. Agroforestry, especially the farm forestry holds great promise as an alternate land use option due to several reasons including the employment and additional income generation and support to horticultural crops. Water resources of the area are adequate, but lowering water table depth and deteriorating quality are raising concerns for policy planners and scientists. The developed model will be of immense helps to different stakeholders' of the UIGP region of India in ensuring optimal natural resources management and sustainable agricultural land use planning. Since, the model is based on scientific wisdom and socio-economic considerations, and thus it may have wider technological adaptability, socio acceptability and economic viability. Above all, it may open up new avenues for resource conservation and utilization under similar agro-ecological conditions occurring elsewhere in the country.

Acknowledgement. Sincere thanks to the Director, ICAR-NBSS&LUP, Nagpur, India for financial support and guidance during the course of study. Thanks to the respondent households for sharing the relevant information for this study.

Conflict of interest. None

REFERENCES

Abrol, I., Alvo, P., De Coninck, F., Eswaran, H., Fausey, N., Gupta, R., Lal, R., Logan, T., MacLeod, D., and McKyes, E. (2012). Advances in soil science: Soil degradation. Springer Science & Business Media.

Agriculture Census. (2015-16). Ministry of Agriculture and Farmers Welfare, GOI, New Delhi. http://agcensus.nic.in › ac_1516_report_final-220221PDF

Arora, S., and Sharma, V. (2017). Reclamation and management of salt-affected soils for safeguarding agricultural productivity. *Journal of Safe Agriculture*, *1*: 1-10.

Brauman, K.A., Siebert, S., and Foley, J.A. (2013). Improvements in crop water productivity increase water sustainability and food security-a global analysis. *Environmental Research Letters*, *8*: 024030.

Census of India. (2011). Ministry of Home Affairs, Government of India. http:// www.censusindia.gov.in.

Chattopadhyay, S. (1997). Designing a sustainable land use pattern-a theoretical exercise. *Geographical Review of India*, *59*: 121-130.

Dadhwal, K.S., Sharma, N.K., and Saroj, P.L. (1995). Diagnosis and possible interventions in designing agroforestry systems in northwestern plains of Uttar Pradesh-a case study. *Indian Journal of Soil Conservation*, *23*(1): 47-53.

Dastagiri, M.B. (2004). Demand and supply projections for livestock products in India. Policy paper 21, National centre for Agricultural Economics and policy Research. 58p.

Dumanski, J., and Craswell, E. (1998). Resource management domains for evaluation and management of agro-ecological systems. In: International Workshop on Resource Management Domains., pp.1-13.

Enahoro, D., Mason-D’ Croz, D., Mul, M., Rich, K.M., Robinson, T.P., Thornton, P., and Staal, S.S. (2019). Supporting sustainable expansion of livestock production in South Asia and Sub-Saharan Africa: Scenario analysis of investment options. *Global Food Security*, *20*: 114-121.

Guo, M., Zhang, T., Li, Z., and Xu, G. (2019). Investigation of runoff and sediment yields under different crop and tillage conditions by field artificial rainfall experiments. *Water, 11*(5): 1019.

Johansen, C., Duxbury, J.M., Virmani, S.M., Gowda, C.L.L., Pande, S., and Joshi, P.K. (eds.). (2000). Legumes in rice and wheat cropping systems of the Indo-Gangetic Plain-Constraints and opportunities. Patancheru 502324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics; and Ithaca, New York, USA: Cornell University. 230 pp.

Kanwar, R. (2010). Sustainable water systems for agriculture and 21st century challenges. *Journal of Crop Improvement*, *24*(1): 41-59.

Khan, S., and Hanjra, M.A. (2009). Footprints of water and energy inputs in food production-global perspectives. *Food Policy*, *34*(2): 130-140.

Khan, M.R., Kumar, A., and Khan, S.A. (2013). Studies on important plant characters of poplar (*Populus deltoides*) for agroforestry system of central Uttar Pradesh. *Journal of Non-Timber Forest Product, 20*(1): 1-5.

Koshal, A.K. (2014). Changing current scenario of rice-wheat system in Indo-Gangetic Plain Region of India. *International Journal of Scientific and Research Publication*, *4*(3): 1-13.

Kumawat, A., Yadav, D., Samadharmam, K., and Rashmi, I. (2020). Soil and water conservation measures for agricultural sustainability. pp.1-23. DOI: http://dx.doi.org/10.5772/intechopen.92895

Lal, R. (2010). Managing soils and ecosystems for mitigating anthropogenic carbon emissions and advancing global food security. *Bioscience, 60*: 59-82.

Mandal, S., Raju, R., Kumar, A., Kumar, P., and Sharma, P.C. (2018). Current status of research, technology response and policy needs of salt-affected soils in India-a review. *Indian Society* of *Coastal Agricultural Research*, *36*: 40-53.

Mehra, M., Singh, C.K., Abrol, I.P., and Oinam, B. (2017). A GIS-based methodological framework to characterize the resource management domain (RMD): A case study of Mewat district, Haryana, India. *Land Use Policy*, *60*: 90-100.

Mennis, J., and Hultgren, T. (2006). Intelligent dasymetric mapping and its application to areal interpolation. *Cartography and Geographic Information Science*, *33*(3): 179-194.

Mukhopadhyay, K., Bera, R., and Pradhan, K. (2004). Impact of soil and socio economic factors on the utilization of agricultural resources: A case study India. *Indian Journal of Landscape Systems and Ecological Studies*, *26*: 65-70.

Narang, R.S., and Virmani, S.M. (2001). Rice-wheat cropping systems of the Indo-Gangetic Plain of India. Rice-Wheat Consortium Paper Series 11. RWC, New Delhi, India.

Neumann, K., Stehfest, E., Verburg, P.H., Siebert, S., Müller, C., and Veldkamp, T. (2011). Exploring global irrigation patterns: a multilevel modelling approach. *Agricultural Systems*, *104*(9): 703-713.

Ochola, W.O., and Kerkides, P. (2004). An integrated indicator-based spatial decision support system for land quality assessment in Kenya. *Computers and Electronics in Agriculture*, *45*(1): 3-26.

Pal, D. K., Bhattacharyya, T., Srivastava, P., Chandran, P., and Ray, S. K. (2009). Soils of the Indo-Gangetic Plains: their historical perspective and management. *Current Science*, *96*(9): 1193-1202.

Panigrahy, S., Upadhyay, G., Ray, S.S., and Prihar, J.S. (2010). Mapping of cropping system for the Indo-Gangetic Plain using multidate SPOT-NDVI-VGT data. *Journal* of the *Indian Society* of *Remote Sensing*, *38*(4): 627-632.

Patil, N.G., Tiwary, P., Bhattacharyya, T., Chandran, P., Sarkar, D., Pal, D.K., Mandal, D.K., Prasad, J., Sidhu, G.S., Nair, K.M., Sahoo, A.K., Das, T.H., Singh, R.S., Mandal, C., Srivastava, R., Sen, T.K., Chatterji, S., Ray, S.K., Obireddy, G.P., Mahapatra, S.K., Anil Kumar, K.S., Das, K., Singh, A.K., Reza, S.K., Dutta, D., Srinivas, S., Karthikeyan, K., Venugopalan, M.V., Velmourougane, K., Srivastava, A., Raychaudhuri, M., Kundu, D.K., Mandal, K.G., Kar, G., Durge, S.L., Kamble, G.K., Gaikwad, M.S., Nimkar, A.M., Bobade, S.V., Anantwar, S.G., Patil, S., Gaikwad, M.S., Sahu, V.T., Bhondwe, H., Dohtre, S.S., Gharami, S., Khapekar, S.G., Koyal, A., Sujatha, K., Reddy, B.M.N., Sreekumar, P., Dutta, D.P., Gogoi, L., Parhad, V.N., Halder, A.S., Basu, R., Singh, R., Jat, B.L., Oad, D.L., Ola, N.R., Wadhai, K., Lokhande, M., Dongare, V.T., Hukare, A., Bansod, N., Kolhe, A.H., Khuspure, J., Kuchankar, H., Balbuddhe, D., Sheikh, S., Sunitha, B.P., Mohanty, B., Hazarika, D., Majumdar, S., Garhwal, R.S., Sahu, A., Mahapatra, S., Puspamitra, S., Kumar, A., Gautam, N., Telpande, B.A., Nimje, A.M., Likhar, C., and Thakre, S. (2014). Natural Resources of the Indo-Gangetic Plains: A land use planning perspective. *Current Science, 107*(9): 1537-1549.

Portmann, F.T., Siebert, S., and Döll, P. (2010). MIRCA2000-global monthly irrigated and rainfed crop areas around the year 2000: a new high-resolution data set for agricultural and hydrological modeling. *Global Biogeochemical Cycles*, *24*(1): GB1011.DOI: 10.1029/2008GB003435

Qureshi, Z., and Neibling, H. (2009). Response of two-row malting spring barley to water cutoff under sprinkler irrigation. *Agricultural Water Management*, *96*(1): 141-148.

Rai, P., Yadav, R.S., Solanki, K.R., Rao, G.R. and Singh, R. (2001). Growth and pruned production of multipurpose tree species in silvo-pastoral systems on degraded lands in semi-arid region of Uttar Pradesh, India. *Forests, Trees and Livelihoods, 11*(4): 347-364.

Ray, S. (2008). Management of Natural Resources-Institutions for Sustainable Livelihoods: The Case of Rajasthan. Academic Foundation, New Delhi.

Rodell, M., Velicogna, I., and Famiglietti, J.S. (2009). Satellite-based estimates of groundwater depletion in India. *Nature, 460*(7258): 999-1002.

Sarkar, A. (2020). Role of livestock farming in meeting livelihood challenges of SC cultivators in India. *Indian Journal of Human Development, 14*(1): 23-41.

Scherr, S. J. (2004). Building opportunities for small-farm agroforestry to supply domestic wood markets in developing countries. In New Vistas in Agroforestry, Springer, The Netherlands. pp. 357-370.

Sehgal, J., and Abrol, I. (1994). Soil degradation in India: Status and impact. Oxford & IBH Publishing Co.

Semwal, R.L., Maikhuri, R.K., and Rao, K.S. (2001). Agriculture-ecology, practices and productivity. Garhwal Himalaya, nature, culture and society. (Eds., Kandari, O.P., and Gosain, O.P.) Trans Meda, Media House Srinagar Garhwal.

Sharma, S.K., Chauhan, S., Sharma, S.K., Kaur, B., and Arya, I.D. (2009). Opportunities and major constraints in agroforestry systems of western UP: a vital role of Star Paper Mills, Saharanpur (UP), India. *Agriculture and Biology Journal of North America, 1*(3): 343-349.

Srivastava, S.K., Thakur, G., and Rai, B. (2012). Conjunctive use of surface and ground water for irrigation with special reference to Mahanadi reservoir project. In India Water Week 2012-Water, Energy and Food Security: Call for Solutions, New Delhi, 10-14 April 2012.

Singh, R. (2000). Environmental consequences of agricultural development: a case study from the green revolution state of Haryana. India. *Agriculture, Ecosystems & Environment, 82*(1): 97-103.

Verma, P., Bijalwan, A., Dobriyal, M.J.R., Swamy, S.L., and Thakur, T.K. (2017). A paradigm shift in agroforestry practices in Uttar Pradesh. *Current Science, 112*(3): 509-516.

Wheater, H. and Evans, E. (2009). Land use, water management and future flood risk. *Land Use Policy, 26* (S1): S251-S264.

How to cite this article: Kumar, A., Lal, S.K. and Meena, R.S. (2021). Management of Natural Resources in Indo-Gangetic Plain Region of India for Sustainable Agricultural Land Use Planning - A Case Study. *Biological Forum – An International Journal*, *13*(2): 282-292.