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A review on agricultural land use planning: A case study of Bhilwara district

R. P. Sharma[2*], R. S. Singh[1] and S. K. Singh[3]

[1]*ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, University Campus, Bohara Ganeshji Road, Udaipur, India*
[2]*Division of Soil Resource Studies, ICAR-National Bureau of Soil Survey and Land Use Planning, Amrawati Road, Nagpur, India*
[3]*ICAR-National Bureau of Soil Survey and Land Use Planning, Amrawati Road, Nagpur, India*

ABSTRACT

The pressure on land resources has increased manifold with the increasing human and animal population. Catering to the needs of this rapidly increasing population was a factor for encroachment on the fallow lands and wastelands, but the lure of cash crops under Green Revolution gradually became a major cause of decline in fallow and waste lands. Therefore, efficient management of land and water resources is a major challenge for the scientists, planners, administrators and farmers to ensure food, water and environmental security for the present and future generations. The new paradigm of Green-Revolution-mediated intensification of cropping has also brought some new challenges as demands from the fast-increasing human and livestock population started to outpace the supply, while the impacts of utter neglect of the traditional strength of the livestock sector, and apathy towards a sustainable agricultural input management policy began to be felt. The soil resource studies can be best utilized for making a rational agricultural land use plan for farming community. In the present study the strategies of agricultural land use planning are highlighted with a case study of Bhilwara. Soil resources of Bhilwara district were assessed for development of sustainable land use plan. The study area has three physiographic units viz. Eastern plain (76.2%), Aravalli (11.36%) and Vindhyan landscape (9.01%) and 11 blocks. The soils has been studied and classified in 40 series. The area receives 600 to 900 mm annual rainfall with potential evapo-transpiration (PET) of 1380 mm. The soils of Bhilwara district has been evaluated for agricultural land use planning for Kharif and Rabi crops and other optimized use; considering the limitations of topography (slope, erosion, stoniness), soil (depth, texture, PSC, AWC), fertility (pH, organic carbon, $CaCO_3$) and salinity (EC, ESP).

Key words:*Concept and strategies, agricultural land use planning, suitability evaluation, semi-arid region*

INTRODUCTION

The Low level of agricultural productivity coupled with inadequate farm and non-farm diversification, low level of technological change and lack of infrastructural facilities of irrigation, roads, market *etc.* act as major constraints to rural development in general ([3]). But high rates of soil erosion, land degradation and groundwater depletion in many regions due to indiscriminate use of land, water and other natural resources have posed additional threat to ecological balance and sustainability of livelihood system of the people. Therefore, any planning for land use should attempt to solve the general problems of under-developed and arrest area specific non-sustainable trends and patterns of development. All types of lands and locations are not equally suitable for profitable, albeit alternative enterprises. Hence, cluster approach to development, based on agro-climatic as well as techno-economic potentials of each region would be essential.

Land use pattern is a reflection of human activities within the boundaries of climatic and edaphic factors [8]. It is also affected by socioeconomic factors and availability of market to sale the produce. In India, number of land use plans has been developed for better and sustainable utilization of natural resources but no one successfully

implemented. The reason is region specific, water shortage for arid region of Rajasthan [8, 9]. The core element in land use planning is the dialogue amongst all participants to reach decisions based on consensus. A major task of land use planning is to accompany and motivate the participants and those affected in order to attain a conciliation of interests concerning land resources, types and extent of land use.

Agricultural land use planning involves making knowledgeable decisions about land use and the environment. Holistic planning involves input from multiple, interrelated data sources and types. In order to achieve this act a great deal of information must be well thought-out simultaneously. Physical and chemical soil information and socioeconomic considerations are vital component in the planning process, reflecting directly upon land use suitability. In India traditional land use planning involved many different sources of printed information such as soil survey manuals, topographic maps, aerial photographs, vegetation surveys, flood maps, hydrology maps, and socio-economic surveys *etc.* Each data source contributed an important characteristic to the final decision. Human decision-makers were challenged to keep track of all this information at once, to understand the interrelationships, and to correlate multiple data sources at single locations.

Today, advances have been made towards extraordinary digital systems for utilization in land use planning. Computer programmes including decision support systems, Geographic Information Systems (GIS), spreadsheets, databases, and color desktop publishing programmes contribute to the speed and efficiency of the overall planning process [17]. A systematic agricultural land use plan is explained by taking a case study of Bhilwara district, Rajasthan for development of formidable land use plan. In first stage the land resources of area was assessed by conducting semi-detailed soil survey using the Survey of India toposheet (1:50,000 scale) as base map following the 3-tier approach [18]. Indian Remote Sensing satellites (IRS 1B) imageries on 1:50,000 scale were visually interpreted for variations in surface features along with SOI toposheets[21]. Soil resources of this district were characterized and classified into 40 series. The soil resource data of Bhilwara were used for assessment of the production potential in association with land capability and irrigability class for its sustainability. To sustain the quality and productivity of soils, it is essential to develop a suitable land use plan in semi-arid region for transfer of right agro-technology at right time and right place.

Strategies of Land Use Planning (LUP)

National Bureau of Soil Survey and Land Use Planning have taken a flagship programme [6] on land resource inventory of India for land use planning. The central element in land use planning is the discussion amongst all participants to reach decisions based on agreement. A major objective of land use planning is to convoy and encourage the participants and those affected in order to attain a conciliation of interests concerning natural resources, distribution, kind and extent of land use. The dialogue-orientated learning and negotiation process amongst the participants leads to the development of their planning capacities and to sustaining mutual support at local level. Participants in land use planning are direct and indirect land users, as well as those affected by the consequences of land use activities. Another group is formed by people who often have political or economic influence; this includes authorities, organizations, middlemen and women, processing industries for agricultural products, *etc.* However, the most important target group in land use planning is farming communities [14].

The Land Use Planning process covers all steps extending from the collection of data and information through its processing, analysis, discussion, evaluation, identification and transfer of right agro-technology at right time and right place. This includes the prerequisites for preparing, initiating and implementing the plan. However, during the LUP process it is not necessary that all planned measures to be carried out will be implemented in totality. For getting best results it is necessary for repeating a process with the aim of approaching a desired goal for implementing the LUP in step-by-step process. It is a repeated or recurring process that seeks to reach an optimal solution. New developments and knowledge gained during the planning process are to be incorporated and may require revision and updating. This may result in a repetition of steps which have already been taken *e.g.* renewed data collection, analysis, discussion and decision. The *fuzzy* model of land evaluation was successfully used by [1] for suggesting sound and intuitive land suitability of the selected benchmark soils in the Indo-Gangetic Plains (IGP) for rice and wheat and in the black soil regions (BSR) for cotton and soybean.

Land use planning is first and foremost a process of clarification and understanding between people who together wish to change something and prepare future actions systematically. In the process, the elements of a plan are worked out for mutual benefits. [4] studied soil degradation status in an irrigated command area of Cauvery which is a rice bowls of Karnataka. It was emphasized for an urgent need to reverse the process of degradation by adopting site-specific interventions and estimated crop loss of Rs 1000 crores every year due to this problem. Such core part of a planning process is therefore a commonly desired objective to be achieved by implementing the plan. Time planning is linked to the physical/geographic/ecological planning of areas, and the two are mutually dependent [15]. Rural areas, in contrast to urban areas are characterized by agricultural and forestry production having relatively low

population and building densities. Infrastructure, facilities or services have a relatively low importance. Land use is considered to be sustainable when it is both socially and environmentally compatible desired by the society, technically viable and when it makes economic sense. This means land use plans should be socially justified, sustainable with wide acceptability and social compatibility. Economically efficient and viable land use plans are first adopted by innovators later on early adopters and majority adopters

Principles of Land Use Planning

Land use planning is orientated to local conditions in terms of both method and content. It considers cultural viewpoints and builds up on local environmental knowledge. The traditional strategies for solving problems and conflicts are very important aspects. The concept of land use planning understands the rural development through a "bottom-up" approach based on self-help and self-responsibility. An approach was suggested by [19] for soils situated on upper rolling plains in semi-arid region for optimization of land use. He recommended pulses or grasses as soil erosion resisting crops with economically important trees, like; citrus, guava and Anola for soils of Bhilwara. Land use planning is a process leading to an improvement in the currently followed production systems. It should have transparency. Therefore, free access to information for all participants is a prerequisite. The differentiation of stakeholders and the gender approach are core principles in land use planning. This is based on interdisciplinary cooperation. Land use planning is an iterative process; it is the flexible and open for refinement based on new findings and changing conditions. Planning should be implementation-orientated.

Implementing the Land Use Planning in Development

Land use planning has to consider how the negotiated decisions and the solutions identified are to be implemented. LUP does not end with the land use plan. The implementation of limited measures (e.g. the development of cultivation techniques which conserve land resources) right at the outset, or parallel to the LUP process, plays an important role in increasing the trust of the people in the village as far as the planning process is concerned. An integrated land use plan has been successfully implemented by [13] in H.D. Kote Taluk of Mysore district for over all development of tribal community. Under this project the constraints in agricultural development were identified by conducting the socio economic survey among local community and subsequently documented the possible solutions for implementation.

Linking present and long-term problems

Land use planning is implemented in order to associate solutions for present problems (e.g. soil erosion, low agricultural production and low farm income in rural households) with the planning towards long-term conservation and sustainable use of land resources [10]. Therefore, any land use planning prgramme should be future-oriented and based on the interests of the participants for their problem-solving.

Chanavada watershed in Girwa tehsil of Udaipur was taken for Land use planning and integrated development by [11]. The area was successfully inventorized and recommended to establish various structures to arrest the soil erosion according to soil slope classes. The suitable locations were also identified to establish new water harvesting structures like Anicut, low cost water harvesting structures and masonry water harvesting structures. The findings were handed over to line departments for execution. But the execution of such recommendations is time taking due to involvement of funds. Under such circumstances; the effective linkage between research institutions and line department plays very important role for community development.

Support in Settling the Conflicts

Agriculture research and extension institutions should share the new ideas to promote integrated land use planning in order to harmonize the objectives related to resource protection with those focused on local economic interests. LUP is used in order to find solutions to conflicts among various groups of the population, among villages, between villages and authorities or large companies, between farmers and pastoralists, *etc.* In this process, rules of using the land are negotiated among the parties involved in the conflict.

Promoting disadvantaged groups

Emphasis is given to the promotion of disadvantaged groups and to improve their access to land resources. Forest degradation and curtailed forest access has reduced the availability of natural food for tribals of H. D. Kote, Mysore [13]on which they were dependent. Under such circumstances these tribals were either migrating for daily wages to nearby towns or restoring to unsustainable harvesting of firewood for their survival income. Therefore, [13] formulated an integrated land use plan for disadvantageous group of peoples for their food security and survival. Tribal women also play an active role in LUP, thus their status in the village and in society has to be increased. On farm training to stakeholders or tribal women on the principle "learning by doing" is intended to improve the planning competence at local level.

The different approaches complement each other and reflect the spectrum of contributions to solutions expected by a process in land use planning. Integrated land use planning should be applied when the biophysical dimension has to be combined with social, political, cultural, economic and legal aspects. In other words, LUP is applied when social conflicts whose origins often lie in the nature of the current land use or in the form of access to resources must be settled.

Optimization of Land Use Planning

Negotiation is required between short and medium-term economic objectives on the one hand and the interests of land resources management on the other as well if positive economic effects are to be expected in the long term run as a result of this negotiation process. Unexplored land use potential has to be identified and evaluated. The existing land use has to be optimized if better options are available. Present and future prospectus for coriander seed production was studied by [20] in south-east Rajasthan i.e. Baran, Bundi, Jhalawar and Kota. The study was conducted on capability of south-east Rajasthan for coriander seed production. The limitations considered for assessment of soil were climatic, topographic, wetness, salinity and alkalinity, soil fertility and physical limitation. The criteria of soil depth, slope, texture, erosion, available water content (AWC) and length of growing period (LGP) were used for assessment of natural resources. Baran, Bundi, Jhalawar and Kota district were recommended as most suitable zone for production of coriander seeds for export purpose. It is a very good source of income for farming community. While studying the natural resources of Karnataka state [12] had identified the potential area based on suitability assessment for medicinal and aromatic plants. Highly suitable and moderately suitable area were mapped in GIS environment and recommended for inclusion of medicinal and aromatic plants in land use planning.

Environmental awareness should also be a part of LUP among the people as well as the authorities. Natural resources should be protected and rehabilitated by: i) planning sustainable land use systems, ii) implementing national and regional objectives with high priority related to the protection of resources iii) setting up biological reserves and conservation areas, iv) monitoring changes in land use to meet the national food security, v) assessment and identifying of the intervention zones and areas for development of projects, planning infrastructural measures such as road-building or irrigation projects aiming at conserving land resources.

Integrating Land Use Plans with Government Policies

Plans for using land resources are made everywhere. Farmers and livestock owners decide which products they want to have in what areas whether to increase or reduce the size of their herds and whether to fence off pasture lands or to keep meadows for growing fodder only. Competing interests in the use of land resources lead to social conflicts. Often, the interests of farmers and tenants are at a disadvantage in comparison to the interests of large companies or authorities. Also, public interests such as the protection of land resources are given too little attention in favour of the short-termgains of individuals in making profit. In addition, there are countless other individual plans by various people, groups and organizations at different levels regarding land use in rural areas.

Naidu [10] characterized and delineated the prime, moderate prime and marginal lands of Andhra Pradesh based on important soil and climatic parameters. It was recommended to state government to develop or frame strong land use legislations to restrict use of prime lands for non agricultural purpose. Pressure on marginal lands has to be reduced by evaluating the capability for a present land use and accordingly suitable alternate land use can be suggested. [13] has developed an integrated land use plan for enhancing tribal livelihood in H.D. Kote Taluk of Mysore district. After conducting the study it was opined that livelihood of tribal's is mainly based on agriculture and allied activities rather than cultivation of crops alone. It was reported that nearly 46% of tribals of H. D. Kote are landless or own small land holdings (<1 ha). To improve livelihood of these peoples, there is a need to focus on integrated land use where all the components of farming system are included to meet the family requirement for food, cash and fodder for livestock.

LUP in Social and Political Context

Planning systems are an expression of social and political conditions in respect of space and time. They are expressed by means of legal regulations (planning laws), social conventions and rules. In addition to codified agreements (laws, administrative regulations), there are others which have been agreed verbally in form of traditional rules of conduct. Those are significant at local level. While studying the effect of climatic and socio-economic factors on under-utilisation of lands in Maharashtra, [2] has observed that rainfall and irrigation factors were playing dominant role in under-utilization of cultivable land in Maharashtra. Availability of finance for opening and deepening wells is another major factor contributing to the under-utilization of agricultural land. The level of underutilization of land reflects the allocative efficiency along with the decision making process and in turn depends on various economic, climatic and institutional factors [16]

Applying Novel Ideas into Practice

It is becoming more and more accepted that land use plans can only be carried out in a sustainable way if they are shared and owned by the people. Nevertheless this realization is rarely translated into purposeful actions. Sahu [17]has pointed out that emerging technology like high resolution satellite data can be utilized successfully for deriving the spatial and temporal agricultural information at micro level. Organizing the satellite derived spatial data and ground observations and non-spatial attribute data, in a remote sensing, GPS and GIS environment, would be highly desirable to facilitate the sustainable development of the specific region. Planning should be shifted from offices and conference rooms to dialogues involving the public. However, there are less success stories where in both concepts and experience how this can be put into practice. The Slogan "per drop more crop" clearly indicates the involvement of drip/sprinkler irrigation system in land use planning for arid/semi-arid regions of India. The ICAR-Central Soil Salinity Research Institute (CSSRI), Regional Research Station, Bharuch (Gujarat) has identified Desi cotton line (G Cot 23) which is tested on salt affected soils and reported salt tolerant and high yielding [5]. This line is known for its short staple characteristics, deep root system, resistance to diseases and pests and drought. This line may be successfully cultivated on salt affected soils of Bhilwara district for better earnings.

LUP with Vertical and Horizontal Linkages

Land use planning is a partially integrating and sector overlapping process. The planning objects are the land resources. Therefore, LUP is not suitable for solving all local problems, nor can it replace the overall planning for an area. The basic technical strategy in LUP is to plan land use according to the suitability and the various needs in the area to be considered. As long as the objectives of land use planning are sufficiently taken into consideration, there is no need to carry out LUP separately. It is experienced by [7] that early soil survey work (1:10000 or larger) or 1: 50000 scale did not provide the desired results due to lack of ancillary data needed for realistic planning and hence geo-referenced information of land use, remote sensing, geo-spatial modeling and decision support system along with associated information (socio-economic, market *etc.*) to be systematically analyzed to have the expected goal of agricultural land use planning on sustainable basis.

Limitations in Practicing Land Use Planning

The extent to which land use planning can actually contribute to solving problems depends on many prerequisites and conditions. It makes no sense to practice land use planning if: The political will is lacking, it cannot be guaranteed that planning will have a binding character, there is no guarantee for the implementation of the plan, other problems have priority to be solved *e.g.* ecologically extreme climatic zone (the Thar Desert); the available scope for action is too small. Apart from this the ecologically sensitive areas such as swamps and marshes and beaches [10] should be protected for their conservation.

A case study of Bhilwara district

Bhilwara district has 10.45 Lakh hectares total geographical area with 7% forest, 11.5% pasture 15-16% culturable waste and 14-18% fallow lands. Net cultivated area varied from 31 to 36% and irrigated area varied between 20 to 30 percent. The study area has three physiographic units *viz.* Eastern plain (76.2%), Aravalli (11.36%) and Vindhyan landscape (9.01%) and classified in 40 series. The area receives 700 mm annual rainfall with potential evapo-transpiration (PET) of 1380 mm. The natural resources were evaluated for various land uses by considering the limitations and potentials and agro-climatic conditions.

Productivity of major crops

Bhilwara district has suitable agro-climatic conditions for various food grain, pulse, oilseed and horticultural crops. There is also very good scope for development of dairy farming because the availability of land resources as pastureland. In *Kharif*season maize is the most widely cultivated crop followed by sorghum, groundnut and cotton in Bhilwara district. During *Rabi* season wheat is cultivated in largest area followed by gram, mustard and barley crops. The average productivity of *Kharif* crops; maize, sorghum, groundnut and cotton is 783, 387, 414 and 332 kg/ha, respectively. In *Rabi* season the average productivity for wheat, gram, mustard and barley is 2119, 969, 797 and 1729 kg/ha, respectively. The productivity of both seasonal crops is rated as low in comparison to national average. There is wide scope for technological interventions to improve the productivity of crops. Harnessing of productive potentials of natural resources up to their full extent is the fundamental key which can be achieved through agricultural land use planning.

Land Suitability assessment for major crops

The modified climatic and land quality requirements [22] for crops are compared with soil and climatic data for suitability of soil. Soil units are evaluated for degree of limitations for individual soil site parameter and individual crops (maize, sorghum, groundnut, castor, soybean, sunflower, pigeon pea, wheat, barley, mustard, gram, safflower and cotton) and define critical values, which determine suitable condition. Soils of Bhilwara district have been evaluated for major crops under rainfed and irrigated condition (Table 2).

Suitability for maize:
Maize performs best in moderately deep (75cm) loam to fine loam, well drained soils. This crop needs more than 500mm rainfall with 105-135 days LGP and AWC >100 mm. Generally, it suits to soils free from salinity and sodicity. Suitable to moderately suitable area for maize in Bhilwara district (Table 2) is 44%. In general suitability of maize is higher in eastern plain followed by Aravalli and Vindhyan region. The occurrence of rock outcrops associated with eroded, shallow, skeletal soils in Aravalli and Vindhyan region is reported the major limitations in maize production. Suitability assessment indicates that 60-80% area of Banera, Hurda and Sahara blocks (Kaliyas, Ganglas, Dhamania and Rajyas series) is suitable for maize production. Suitable area for maize is reported <25% in Jahazpur and Mandalgarh blocks (Kajlodiya, Dhamania and Kaliyas series).

Suitability for sorghum:
Sorghum is ideally suited for area receiving >600 mm rainfall with LGP 105-135 days. It requires moderately well drained, loam to fine textured soils with depth >75 cm and AWC >100 mm. It tolerates moderate levels of salinity and sodicity. In Bhilwara district (Table 2) 65% area is suitable to moderately suitable for sorghum. In eastern plain suitable to moderately suitable area is 77% as compared to 40% in Aravalli and 16% in Vindhyan region. Suitable to moderately suitable area is more than 80% in Banera, Hurda, Sahara and Shahpura blocks comprised of Ganglas, Dhamania and Kaliyas series.

Suitability for groundnut:
Groundnut requires 500-700 mm rainfall with 105-135 days LGP, well drained, loam to fine loam soils with depth exceeding 50 cm, AWC exceeding 100 mm, free from salinity and sodicity. In Bhilwara district (Table 2) 25% area is suitable to moderately suitable for groundnut. Suitable area for groundnut is 11-13% in Asind and Raipur tehsil comprised of Jaitpura and Hathisar series. Moderately suitable area is between 30-50% situated in Banera, Bhilwara, Hurda, Mandal and Sahara tehsil comprising mainly Ganglas, Hurda and Kaliyas series.

Suitability for soybean:
Soybean is suitable for areas receiving >600 mm rainfall with LGP 105-135 days. It requires moderately well drained, fine textured soils with depth exceeding 75 cm and AWC >150 mm. It is sensitive to saline sodic condition. In Bhilwara district (Table 2) soybean production is suitable to moderately suitable in 28% area. Suitable area for soybean is mainly situated in Aravalli region (35%). The blocks suitable for soybean production are Asind and Raipur comprised of Jaitpura and Haithisar series whereas in 40-60% area of Banera, Hurda, Raipur and Sahara (Ganglas, Kaliyas and Rajyas series) are moderately suitable.

Suitability for wheat and barley:
Wheat and barley are ideally suited under irrigated condition with 400 mm precipitation/irrigation. It requires well drained, slight to moderately eroded, deep, medium textured soils with AWC >100 mm. Wheat is tolerant to moderate sodicity and erosion, whereas, barley is tolerant to salinity and sodicity. Water requirement of barley is relatively lower as compared to wheat, therefore, barley is recommended in place of wheat under limited irrigation condition. In Bhilwara district (Table 2) 37% area is suitable for wheat and barley mainly situated in Aravalli and eastern plain. Suitable area for wheat and barley is 69% in Sahara block and between 40-60% in Banera, Hurda, Mandal and Raipur blocks constituting Jaitpura, Patan, Ganglas, Kaliyas, Rajyas and Rakshi series.

Suitability for Mustard:
Mustard requires 300 mm irrigation with LGP of 120 days. It is ideally suited to well drained, medium to fine textured, deep soil with AWC of >100 mm. It is moderately tolerant to salinity and sodicity. In Bhilwara district (Table 2), 37% area is suitable for mustard which constitutes 40% area of Aravalli and 41% area of eastern plain. Suitable area for mustard is 69% in Sahara block and between 40-60% in Banera, Hurda, Mandal and Raipur blocks comprised of Kaliyas, Rajyas, Jaitpura, Patan and Ganglas series. Major portion of dominant soils in Mandal and Raipur and part of Bhilwara blocks are suitable for mustard production.

Suggested land use plan for Bhilwara district
Out of 40 soil series of Bhilwara district, six series (Hathisar, Jaitpura, Patan, Kaliyas, Ganglas and Rajyas) are evaluated as suitable to moderately suitable for major *Kharif* and *Rabi* crops. It was estimated that about 30-35% area of Jaitpura, Patan, Dhamania, Ganglas, Kajlodiya, Kaliyas, Rajyas and Rakshi soil series is evaluated as suitable to moderately suitable for major *Kharif* and *Rabi* crops. Only 15-20% area of seven soil series (Kirimar, Atoli, Baland, Gandher, Ganeshpura, Motipura and Nayagaon) is found moderately to marginally suitable for major crops due to soil physical (shallowness, gravelly skeletal, stoniness, slope and severe erosion)and chemical (salinity and sodicity) limitations.

The soils graded as "not suitable for cultivation" due to limitations of shallow skeletal (Kolpura, Jahazpur, Ladpura, Bantal, Tikar, Inani, Khumanpura, Lachhmi series) covered 14-16% area, limitation of salinity and sodicity (Barach, Dablachanda, Motipura, Baland, Bawari, Ganeshpura, Bhilakhera and Dhanop series) covered 18-20% area and limitation of rock outcrops, covered 13.7% area. These series are moderate to marginally suitable for grasses like *Cenchrusciliaris* and *Sporobolus sp.* for feeding the livestock. These soils are also moderately suitable for setting up a social forestry or village forestry. The trees *Atriplex, Casuarina equistefolia, Prosopisjuliflora*and *Tamarix articulate* can easily be planted to meet out wood and timber requirement for local communities. Such plantations need proper care only for a period of 6-7 years. After full establishment of tress the leaves may be utilized as fodder for small ruminants (sheep and goats and their exotic relatives). Apart from this it would also be helpful to purify the atmosphere of the region.

Soils of Bhilwara and Dhanop series are suitable for salt tolerant grass and tree species. In the district Kolpura, Khumanpura, Tikar, Bantal, Jahazpur, Bhana, Inaini, Lachhmi, Ladpura, Genoli and Tilasva series have limitation of depth, slope and erosion. These series are not suitable for field crops. Lachhmi and Tilasva series are suitable for *Cenchrusciliaris* whereas other soil series are moderate to marginally suitable for development as grassland. Tikar, Genoli and Tilasva series are suitable for *Commiferamukul* and *Aloevera*. Bantal, Kolpura and Lachhmi series are moderately suitable for trees especially *Prosopisjuliflora, Acacia senegal, Commiferamukul*and *Aloevera*. Soils of Khumanpura, Jahazpur, Bhana and Ladpura series are marginally suitable for the tree species. Land reclamation, soil and water conservation measures and provision for drainage should be planned in areas where salinity/sodicity and drainage problems is reported to improve and maintain the sustainability [10].

On current land use pattern the area under *Kharif*crops is around 2.82 lakh ha. Area and productivity of major crops in Bhilwara district is given in table 1. In *Kharif* season the major area is occupied by maize and sorghum due to socio-economic issues whereas this area is evaluated as suitable for castor, soybean, sunflower and cowpea. It was reported that area under these crop is insignificant. Pulses and oilseed crops have received attention of government and policy makers with a clear cut message to increase productivity and production. This study revealed that the soils of this study area are suitable for pulses and oilseed crops. Therefore, efforts should be made for diverting maize/sorghum growing areas to oilseed and pulses which has relatively low water requirement and also suitable in the agro-ecological environment [21].

Table 1. Area, productivity and potential of major crops in Bhilwara district

Crops	Cropped	Irrigated	Productivity	Suitable Area (ha)		Suitability Index
	----------ha----------		kg ha^{-1}	S1	S1+S2	
Sorghum	30609	80	387	338899	675519	54.15
Maize	155386	14409	783	293551	459496	49.95
Groundnut	18503	1570	414	25462	264105	29.10
Cotton	15913	14805	332	1763	418190	34.80
Tur	12	1	917	597	144215	25.56
Sugarcane	440	440	4985	--	249880	28.58
Wheat	89919	86633	2113	294380	397216	44.82
Barley	15108	13670	1729	294380	606846	47.82
Gram	44019	7485	969	--	152480	27.18
Mustard	20295	14586	797	292610	387216	44.78
Soybean	-	-	-	25462	287694	32.62
Castor	-	-	-	109485	284185	34.52
Sunflower	-	-	-	246110	593897	50.14
Safflower	-	-	-	25462	290255	30.21
Cowpea	-	-	-	129785	293551	32.84

On current land use pattern the area under *Rabi* crops is around 1.78 lakh ha. In Rabi season the area under wheat cultivation is reported substantially higher than mustard. Wheat is staple food for farming community of the district. Therefore, the farmers are more inclined to wheat cultivation. It has been reported that study area has scanty water resources. Keeping, the concept of sustainability within the existing resources mustard has been recommended for *Rabi* season because it has low water requirement. Therefore, sizeable area from wheat can be diverted to mustard which would help in the soil sustainability or quality. It would be a good source of edible oil for local public and protein rich cake as feed for animals. Based on soil resource evaluation, it is observed that the soils of Banera, Hurda, Sahara and Shahpura tehsil have higher potential whereas soils of Bhilwara and Kotri has medium and Jahazpur, Mandalgarh and Raipur has low potential for *Rabi* crop production.

In drought years, during kharif season it is observed that sorghum performs better in Mandalgarh whereas maize in Jahazpur and Banera tehsil. Among oil seed crops, performance of sesame is better in Mandalgarh and Jahazpur whereas groundnut is better in Mandalgarh and Kotri tehsil. In *Rabi* season crops the overall productivity is high in

Mandalgarh and Raipur tehsil, medium in Hurda and Sahara and low in Banera, Bhilwara and Shahpura tehsil. In these tehsils, the productivity of mustard is better as compared to wheat and barley. Relative productivity of wheat is higher in Mandalgarh and Raipur tehsil and low in Banera, Bhilwara and Shahpura tehsil. Productivity of barley is high in Mandalgarh and low in Banera, Bhilwara and Shahpura tehsil. In drought conditions, sorghum, sesame and groundnut crops are recommended in *Kharif*season for Mandalgarh whereas maize is recommended for Banera, and Jahazpur tehsil. Productivity of *Rabi* crops is depends on irrigation facility in conjunction with soil characteristics. In *Kharif*, the productivity is affected by the quantum and duration of rainfall. The present level of productivity can be improved by intervention in terms of fertilizer application especially in areas under intensive farming system and irrigated as compared to rain fed. Impact of drought is relatively high on productivity of sorghum and Bajra and low in maize, sesame and groundnut.

Table 2. Soil suitability for major crops in physiographic units and blocks of Bhilwara district

Landforms	Maize	Sorghum	Groundnut	Castor	Soybean	Sunflower	pigeon pea	Wheat	Barley	Mustard	Gram	Safflower	Cotton
	Suitable plus moderately suitable (% area)												
Aravalli	40	40	35	35	35	35	0	40	40	40	35	35	35
Eastern plain	49	77	28	30	30	67	17	41	56	41	43	31	46
Vindhyan	20	16	3	6	6	16	6	16	16	16	16	5	11
Tehsil													
Asind	48	57	33	37	37	49	5	40	46	40	38	37	38
Banera	64	80	45	41	46	75	19	63	76	63	63	47	63
Bhilwara	42	74	31	32	31	67	19	40	55	40	40	33	40
Hurda	62	83	41	37	41	78	14	54	70	54	54	41	54
Jahazpur	23	52	2	2	2	37	2	11	24	11	16	2	19
Kotri	38	75	14	14	13	63	9	29	49	29	38	14	31
Mandal	54	63	37	41	42	55	20	48	56	48	46	42	46
Mandalgarh	20	34	4	6	6	28	6	15	22	15	15	5	20
Raipur	56	56	41	47	47	55	25	48	48	48	47	47	47
Sahara	80	80	52	66	67	80	51	69	69	69	69	67	69
Shahpura	40	88	17	18	17	76	7	33	47	33	39	16	49
District	**44**	**65**	**25**	**27**	**28**	**57**	**14**	**37**	**49**	**37**	**38**	**28**	**40**

CONCLUSION

The present study concludes that in Bhilwara district, the wheat cultivation is recommended to continue with adoption of improved varieties with draught tolerance mechanism. Large area of district is reported higher in soluble salt content in soil as well as ground water therefore; part of wheat growing area with higher EC may be diverted to mustard crop due to its higher level of tolerance and less number of irrigation which minimize the salinity /sodicity build up in the soil. The areas which are shallow, undulated, rocky lands are recommended to be utilized for social forestry, village forestry, pasture for livestock and recreational purposes. Such area may also be utilized for rain water harvesting for underground recharge. It has been reported that soybean and castor is best fit in large area of district according to suitability assessment of soil resources but these crops are not being cultivated due to lack of knowledge and socio-economic issues. To implement such recommendations on farm demonstration trials should be conducted by concerned KVK at farmer's field. There is strong political will to enhance the pulse production in country. The pulses like green gram(*Vigna radiate*), black gram (*Vigna mungo*)and chickpea (*Cicer arietinum*)are recommended for cultivation on class III land (Shahpura 57%, Kotri-45%, Hurda-42% and Bhilwara-40% area) for preserving the natural resources to further degradation, erosion hazards and maintain the soil quality and sustainability. The area with 20-35% rock out crops may be treated as plus point for surrounding cropped area because they are very useful source of rainwater harvesting and nutrients. Such cropped land may be intensively managed to boost up the crop production. District level land resource information for different stakeholders is generated for initiating research programmes, technology transfer and implementation of developmental programmes by different agencies.

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