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# Agricultural land use planning of Bhilwara district, Rajasthan

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**Abstract:** The pressure on land resources has increased manifold with the increasing human and animal population. 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 soil resource information can be best utilized for making a rational agricultural land use plan for farming community. In the present study the 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 area receives 600 to 900 mm annual rainfall with potential evapotranspiration (PET) of 1380 mm. The soils were studied and classified in 40 series. Theset were 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**: *Agricultural land use planning, Land capability classes, Irrigability classes, suitability evaluation, Bhilwara*

## 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 (Haque 1999). 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 (Joshi 2014). It is also affected by socio-economic factors and availability of market to sell the produce. In India, number of land use plan have been developed for

better and sustainable utilization of natural resources but acceptance and implementation of these plans is very low. The region specific reason, for arid region of Rajasthan (Joshi 2014; Kar 2014) is water shortage. An approach on land use was suggested by Sharma (2008) for soils situated on upper rolling plains of Bhilwara to promote pulses or grasses as soil erosion resisting crops with economically important trees, like; citrus, guava and Anola. Sometimes the land use plan for a specific crop for a particular region; such as land use plan for coriander production in south-east Rajasthan (Sharma *et al.* 2014) can be more effective for implementation. The mission on 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.

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. A systematic agricultural land use plan is explained by taking a case study of Bhilwara district, Rajasthan for development of 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 (Sehgal *et al*. 1989). Indian Remote Sensing satellites (IRS 1B) imageries on 1:50,000 scale were visually interpreted for variations in surface features along with SOI toposheets. 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.

## Materials and Methods

### *Soil resources and mapping*

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%) 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.

### *Sustainability evaluation*

Soil sustainability was evaluated using cumulative rating index (CRI) under given set of management through combining of soil data (Lal 1996). Weighting factors for relevant indicators (soil parameters) were combined into a cumulative index. The following 12 soil parameters have been used in this study:

| | | | |
|---|---|---|---|
| 1. | Topography | - | slope, erosion, stoniness |
| 2. | Soils | - | depth, texture, particle size class, available water content (AWC) |
| 3. | Fertility | - | pH, organic carbon, $CaCO_3$ |
| 4. | Salinity | - | EC, ESP |

Each parameter has been assigned the value from 1 to 5 for their relative high to low sustainability ratings depending upon the suitability for a particular land use. Following criteria have been used for assessing the sustainability.

| Class | Sustainability class | Cumulative rating index |
|---|---|---|
| 1. | Highly sustainable | <24 |
| 2. | Sustainable | 24-30 |
| 3. | Sustainable with high input | 30-36 |
| 4. | Sustainable with another land use | 36-48 |
| 5. | Unsustainable | >48 |

*Suitability evaluation*

Soil suitability for crop production depends on soil properties affecting root ramification and supply of moisture and nutrients and other factors like topography and climate. Potentials and constraints of soil need to be assessed and interpreted for better land use planning. USDA land capability classification (Klingebiel and Montgomery 1961), irrigability classification (IARI 1971) was used for interpretation of land use properties and land use planning.

*Land use options*

There are two orders (S for suitable and N for non-suitable), reflecting kinds of suitability with three classes (S1-S3) under the order S and two classes (N1-N2) within the order N, reflecting degrees of suitability (FAO 1976 as described by Sys *et al*. 1991). Subclass shows the kind of limitation or improvement measures to be undertaken within class. The limitations are c: climatic limitation; t: topographic limitation; w: wetness; n: salinity and alkalinity; f: soil fertility; s: physical limitation. The framework comprises the following activities:

- Selection of relevant kinds of land use and its requirement.
- Description of land units and assessment of land qualities.
- Matching, comparisons of land use requirements with land qualities for each land on each soil unit.
- Provisional suitability classification.
- Economic and social analysis.
- Final suitability classification

Land qualities are usually rated on a scale ranging from 1 (very good) to 5 (very poor). These ratings are compared with requirements of a given land use. Requirements are expressed as suitability class limits per land quality. Overall suitability is accounted as:

S (suitable): Land on which sustained use of the land under consideration is expected to yield benefits, which justify the inputs without unacceptable risk to land resources.

S1 (highly suitable): optimum conditions for plant growth. (S1-2) has slight limitation, not more than one correctable moderate limitation.

S2 (moderately suitable): land units representing nearly optimal conditions; affect productivity by 20% or less; have slight and no limitation or more than 3 moderate limitations.

S3 (marginally suitable): land units representing moderate conditions; affect productivity significantly but still marginally economical, have more than 3 moderate limitations and not more than one severe limitation (correctable) that however, does not exclude the use of land.

Order 'N' not suitable: Land, which has qualities that appear to preclude its sustained use.

N1 - Land units(s) having limitations, which may be surmountable with time, have a severe limitation that excludes the use of the land or more than one severe limitation that cannot be corrected.

N2 - Not suitable land – land unit(s) having limitations, which appear so severe to preclude any possibilities of successful sustained use of land in a given manner.

**Results and Discussions**

*Generalized soil-site characteristics*

Soil resources of Bhilwara district were assessed through semi detailed survey 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 40 series. The area receives 700 mm annual rainfall with potential evapotranspiration (PET) of 1380 mm. It was found that 13 soil series (11.80% area) are highly sustainable (Table 1) with cumulative rating index (CRI) <24, 17 series (54.74% area) are sustainable (CRI 24-30), seven series (11.62% area) are sustainable with high input (CRI 30-36) under existing land use system and three series (4.69% area) are sustainable (CRI 36-48) with another land use. This area is capable to support all major field crops.

Soil series of eastern plain are moderately shallow to moderately deep loamy in texture with high pH (8.42). Soils of Aravalli landscape are mostly shallow to moderately shallow, relatively coarser in texture with high pH (8.25). Soils of Vindhyan landscape are shallow, relatively finer in texture with average pH (7.86). Eastern plain is situated at an elevation of 320-700 m above msl. It has 90 % area with leveled (<1%) to very gentle slope (1-3%). About 10% area is covered by hilly terrain and undulating pediments with rock outcrop. Aravalli landscape is mainly situated at an elevation of 420 to 600 m above msl with 44% area under leveled (<1%) to very gentle slope (1-3%) and remaining area in hilly terrain and pediments with pockets of intervening valleys. Vindhyan landscape is mainly situated at an elevation of 510 to 570 m above msl. It is constituted with undulating plateau/hills (80%) with valley portions (19.5%).

**Table 1**. Sustainability assessment* of soil series of Bhilwara district

| Series | Topography | Soil | Fertility | Salinity | Cumulative rating index (CRI) | Sustainability class |
|---|---|---|---|---|---|---|
| | Slope, erosion, stoniness | Depth, texture, PSC,AWC | pH, O.C, CaCO3 | EC,ESP | | |
| Patan | 5 | 9 | 7 | 2 | 23 | 1 |
| Atoli | 4 | 4 | 10 | 4 | 22 | 1 |
| Bhilakher | 4 | 8 | 8 | 3 | 23 | 1 |
| Dhamania | 6 | 8 | 8 | 2 | 24 | 1 |
| Ganeshpur | 4 | 6 | 8 | 2 | 20 | 1 |
| Hurda | 6 | 8 | 7 | 2 | 23 | 1 |
| Rakshi | 6 | 7 | 7 | 2 | 22 | 1 |
| Hem Niwas | 6 | 9 | 4 | 2 | 21 | 1 |
| Japarpura | 4 | 6 | 7 | 2 | 19 | 1 |
| Mandalgarh | 5 | 10 | 6 | 2 | 23 | 1 |
| Nayagaon | 5 | 4 | 7 | 2 | 18 | 1 |
| Ritya Khera | 5 | 6 | 6 | 2 | 19 | 1 |
| Tharod | 5 | 5 | 9 | 2 | 21 | 1 |
| Hathisar | 5 | 11 | 6 | 2 | 24 | 2 |
| Jaitpura | 5 | 12 | 6 | 2 | 25 | 2 |
| Kirimar | 6 | 11 | 8 | 3 | 28 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Baland | 5 | 10 | 9 | 4 | 28 | 2 |
| Dabla Chanda | 6 | 11 | 9 | 3 | 29 | 2 |
| Dhanop | 5 | 9 | 11 | 3 | 28 | 2 |
| Gandher | 6 | 8 | 9 | 2 | 25 | 2 |
| Ganglas | 6 | 11 | 7 | 2 | 26 | 2 |
| Kajlodiya | 5 | 9 | 8 | 2 | 24 | 2 |
| Kaliyas | 6 | 11 | 7 | 2 | 26 | 2 |
| Lachhmi | 7 | 13 | 7 | 2 | 29 | 2 |
| Motipura | 5 | 8 | 10 | 2 | 25 | 2 |
| Rajyas | 6 | 10 | 7 | 2 | 25 | 2 |
| Santokpur | 6 | 13 | 8 | 2 | 29 | 2 |
| Genoli | 8.5 | 15 | 4 | 2 | 26 | 2 |
| Kotwal ka Khera | 5 | 11 | 6 | 2 | 24 | 2 |
| Tilasva | 6 | 14 | 4 | 2 | 26 | 2 |
| Barach | 6 | 16 | 8 | 2 | 32 | 3 |
| Bhana | 9 | 17 | 7 | 2 | 35 | 3 |
| Bantal | 9 | 16 | 7 | 2 | 33 | 3 |
| Inaini | 8 | 15 | 9 | 2 | 34 | 3 |
| Jahajpur | 14 | 18 | 6 | 2 | 35 | 3 |
| Tikar | 9 | 15 | 8 | 2 | 33 | 3 |
| Ladpura | 11 | 17 | 5 | 2 | 35 | 3 |
| Khumanpura | 10 | 17 | 8 | 2 | 37 | 4 |
| Kolpura | 14 | 19 | 5 | 2 | 40 | 4 |
| Bawari | 6 | 15 | 11 | 5 | 37 | 4 |

*1: Highly sustainable (<24)-11.80%; 2: Sustainable (24-30)-54.74%; 3: Sustainable with high input (30-36)-11.62%; 4: Sustainable with another land use (36-48)-4.69% area.

*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 of the availability of land resources as pastureland. In *kharif* season maize is the most widely cultivated crop followed by sorghum, groundnut and cotton. During *Rabi* season wheat is cultivated in large 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 (Table 2). In *rabi* season the average productivity for wheat, gram, mustard and barley is 2119, 969, 797 and 1729 kg/ha, respectively (Table 2). 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.

**Table 2.** Area and productivity potential of major crops in Bhilwara district

| Crops | Cropped | Irrigated | Productivity | Suitable Area (ha) | | Suitability |
|---|---|---|---|---|---|---|
| | ----------ha---------- | | (kg ha$^{-1}$) | S1 | S1+S2 | Index |
| 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 |

*Land capability classification (LCC)*

Land Capability Class (LCC) is the grouping of a land unit into defined classes based on the capability. It serves as a guide to assess suitability of the land for arable crops (Class I-IV), grazing and forestry (class V-VIII). In Bhilwara district (Table 3), 63% area is under land capability class II-III and 19.6% in class IV and V. Class II and class III land is predominant in eastern plain, whereas, in Vindhyan region land capability class II and III constitute 19.5% and in Aravalli 38.3%. The class IV and V land is 33.2% in Vindhyan and 20.8% in Aravalli plain. This indicates that the soils of the eastern plain are higher in LCC category followed by Aravalli and Vindhyan. Class II and III land is more than 80% in Banera, Hurda and Sahara tehsil mainly in eastern plains comprising of Kaliyas, Ganglas, Dabla Chanda and Dhamania series. In Jahazpur and Mandalgarh tehsil class II-III land is between 33-48% comprising mainly Dabla Chanda, Baland and Motipura series and class IV and V land is 30% comprising mainly Jahazpur and Ladpura series. In other tehsils class II and III land is 50-70% and class IV and V land is 10-20%.

**Table 3** . Landform and block wise land capability classes

| Landform | Land Capability Class | | | | | Index* |
|---|---|---|---|---|---|---|
| | I | II | III | IV | V | |
| | | | (%) | | | |
| Aravalli | 2.13 | 32.77 | 5.54 | 0.80 | 22.01 | 36.39 |
| Eastern plain | 0.00 | 34.99 | 39.67 | 6.38 | 5.81 | 55.51 |
| Vindhyan | 0.00 | 6.13 | 13.38 | 6.19 | 27.02 | 20.81 |
| **Tehsil** | | | | | | |
| Asind | 1.30 | 35.88 | 20.29 | 5.99 | 11.36 | 46.85 |
| Banera | 0.00 | 48.07 | 32.05 | 13.71 | 2.89 | 63.75 |
| Bhilwara | 0.00 | 34.10 | 40.22 | 9.28 | 3.18 | 55.76 |
| Hurda | 0.01 | 41.10 | 41.48 | 10.77 | 1.51 | 62.39 |
| Jahazpur | 0.00 | 9.19 | 39.39 | 4.27 | 24.54 | 37.60 |
| Kotri | 0.00 | 25.70 | 44.65 | 5.86 | 16.16 | 52.93 |
| Mandal | 0.00 | 43.20 | 20.19 | 9.21 | 9.22 | 52.20 |
| Mandalgarh | 0.00 | 7.77 | 25.67 | 5.03 | 24.80 | 28.59 |
| Raipur | 2.01 | 44.86 | 9.10 | 3.44 | 5.08 | 45.75 |
| Sahara | 0.00 | 67.16 | 13.16 | 8.52 | 3.49 | 65.73 |
| Shahpura | 0.00 | 24.40 | 57.15 | 1.84 | 7.32 | 56.01 |
| District | 0.24 | 30.94 | 32.06 | 6.73 | 12.87 | 49.49 |

*Land capability class I, II, III, IV and V-VIII were assigned weight of 5, 4, 3, 2 and 1, respectively for developing LCC index)

LCC index is more than 60 in Banera, Hurda and Sahara tehsil (Table 3) indicating higher level of suitability for crop production. LCC index is between 40-60 for Asind, Bhilwara, Kotri, Mandal and Shahpura tehsil indicating dominance of class III land. LCC index is <40 in Jahazpur and Mandalgarh tehsil where the class IV and V land exceeds 25% besides significant area under rock outcrops. Class IV and V lands which are not suitable for cultivation are mainly concentrated in north eastern part in Jahazpur and in pockets in central part of the district and western fringe. In central part of the district most of the dominant soils are class II and associated soils are graded as class III land. Both dominant and subdominant soils of Shahpura and Kotri tehsil belong to LCC class III. Rockout crops in southern part of Mandalgarh tehsil are associated with class IV soils whereas rock outcrops in northwestern of Asind are associated with class II. Major part of valley portion of Mandalgarh is categorized in class III.

*Irrigation capability classification (ICC)*

In Bhilwara district (Table 4) 25.8% area is under ICC class 1; highly suitable for irrigation. Area under class 2-3 (suitable to moderately suitable) is 41% whereas 16.1% area is reported marginal to not-suitable for irrigation. Suitable area for irrigation is higher for eastern plain (45.8%) as compared to 34.9% in Aravalli and 16.2% in Vindhyan region. In eastern plains 33% area is moderately suitable for irrigation. However, area under rock outcrops (22-33%) of Aravalli and Vindhyan

is marginal to not suitable for irrigation. In general, irrigation suitability is higher in eastern plain due to medium textured and deep soils whereas in Aravalli and Vindhyan soils depth and slope are major limiting factors. Area suitable for irrigation (class 1 and 2) is >65% in Banera and Sahara tehsil. Based on ICC index (Table 4), suitability for irrigation is high in Banera, Bhilwara, Hurda, Mandal, Sahara and Shahpura tehsils, very low in Mandalgarh and Jahazpur tehsils and moderate in Asind, Kotri and Raipur tehsils comprising mainly Ganglas, Kaliyas and Rajyas series. Area not suitable for irrigation is around 30% in Jahazpur and Mandalgarh tehsil. In these tehsils area under ICC 2 and 3 is only 30-45% comprising mainly Jahazpur, Bantal, Bawari and Ladpura series. Area under ICC class 2 and 3 comprised mainly Dabla Chanda, Kajlodya, Motipura and Dhamania series.

In the district, majority of area suitable for irrigation is situated in central and south west part where dominant soils are highly suitable and subdominant soils are suitable for irrigation. The dominant soils in east-central part of the district especially in Shahpura and Kotri tehsil are moderately suitable and associated with soils which are under suitable category. Rockout crops in Mandalgarh and soils in north east part in Jahazpur tehsil are not suitable for irrigation. Valley soils in Mandalgarh tehsil and associated soils with rock outcrops in Asind and Mandal tehsil are evaluated as suitable for irrigation.

**Table 4.** Landform and block wise irrigation capability classes

| Landforms | Irrigation Capability Class | | | | | Index |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| | ---------- (%) ---------- | | | | | |
| Aravalli | 15.60 | 19.31 | 5.54 | 0.80 | 22.01 | 39.09 |
| Eastern plain | 31.27 | 14.58 | 33.43 | 5.76 | 8.01 | 52.74 |
| Vindhyan | 1.87 | 14.43 | 3.21 | 6.19 | 27.02 | 23.22 |
| **Tehsil** | | | | | | |
| Asind | 26.76 | 10.87 | 22.08 | 3.75 | 11.36 | 52.48 |
| Banera | 47.91 | 17.88 | 25.54 | 2.50 | 2.89 | 79.11 |
| Bhilwara | 34.08 | 18.38 | 29.16 | 2.08 | 3.18 | 67.75 |
| Hurda | 40.96 | 15.81 | 30.16 | 6.42 | 1.51 | 74.58 |
| Jahazpur | 1.97 | 12.03 | 34.58 | 11.69 | 17.12 | 40.44 |
| Kotri | 14.38 | 20.64 | 36.47 | 6.22 | 14.66 | 58.19 |
| Mandal | 38.97 | 7.09 | 23.42 | 6.06 | 6.50 | 62.42 |
| Mandalgarh | 3.30 | 14.75 | 15.38 | 5.85 | 23.97 | 31.47 |
| Raipur | 35.5 | 11.4 | 12.3 | 5.7 | 10.7 | 56.43 |
| Sahara | 67.00 | 1.60 | 19.40 | 4.30 | 0.60 | 81.80 |
| Shahpura | 17.0 | 26.5 | 39.8 | 0.4 | 11.7 | 64.57 |
| District | 25.76 | 14.61 | 26.39 | 5.04 | 11.04 | 57.51 |

*Sustainability assessment*

Based on cumulative rating index for 12 parameters, sustainability of land use in Bhilwara district has been assessed. This system of assessment is a general indicator in a given set of condition; however, site specific empirical relationship needs to be established between cumulative rating index and one or several indices of sustainability.

According to CRI methodology, out of 40 soil series of Bhilwara district 13 are graded as sustainability class 1 (Table 1) which constitutes 11.8% area. This is highly suitable for major field crops in the region as per present agro-climatic condition. These soils can be put under the practice of intensive agriculture to achieve higher productivity level. Sixteen soil series are graded as sustainability class 2. These series occupy 54% area of the district and can be used for farming without much degradation. Eight series (11.8% area) are rated as sustainability index 3 which have low sustainability for field crops. These are marginally suitable or not suitable for field crops. Regular cropping of these soils would require high input management and may lead to degradation under existing land use pattern. Three soils series are reported in sustainability index 4 (4.7% area). These are not sustainable for cultivation of field crops. The soils with sustainability index 3 and 4 may be best utilized for pasture, shrubs, tree plantation or wild life and recreational purposes to prevent further degradation.

*Land suitability assessment for major crops*

The modified climatic and land quality requirements (Sys *et al.* 1991) 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 defined critical values, which determine suitable condition. Soils of Bhilwara district have been evaluated for major crops under rainfed and irrigated conditions (Table 5). The scope for production of major field crops in study area is described as follows.

*Suitability for maize*

Maize performs best in moderately deep (75 cm) loam to fine loam, well drained soils. This crop needs more than 500 mm rainfall with 105-135 days length of growing period (LGP) and available water capacity (AWC) >100 mm. Generally, it suits to soils free from salinity and sodicity. Suitable to moderately suitable area for maize in Bhilwara district (Table 5) is 44%. In general, suitability of maize is higher in eastern plains followed by Aravalli and Vindhyan region. The occurrence of rock outcrops associated with eroded, shallow, skeletal soils in Aravalli and Vindhyan region is reported as the major limitation 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 5) 65% area is suitable to moderately suitable for sorghum. In eastern plains suitable to moderately suitable area is 77% whereas as 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.

**Table 5.** Soil suitability for major crops in physiographic units and blocks of Bhilwara district

| Land forms | 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 |

*Suitability for groundnut*

Groundnut requires 500-700 mm rainfall with 105-135 days LGP, well drained, loam to fine loam soils with >50 cm depth, AWC exceeding 100 mm, free from salinity and sodicity. In Bhilwara district (Table 5) 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 5) 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 conditions 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 5) 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 5), 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 are 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) are 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, Dabla chanda, 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 *Cenchrus ciliaris* 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, Prosopis juliflora* 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).

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 *Cenchrus ciliaris* whereas other soil series are moderate to marginally suitable for development as grassland. Tikar, Genoli and Tilasva series are suitable for *Commifera mukul* and *Aloevera*. Bantal, Kolpura and Lachhmi series are moderately suitable for trees especially *Prosopis juliflora, Acacia senegal, Commifera mukul* 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 (Naidu *et al.* 2014).

*Land use planning for kharif crops*

Currently the area under *kharif* crops is around 2.82 lakh ha. Area and productivity of major crops in

Bhilwara district is given in table 2. 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 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.

*Land use planning for rabi crops*

Currrently 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. 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 have low potential for *rabi* crop production.

*Land use planning in drought conditions*

In drought years, it is observed that *kharif* sorghum performs better in Mandalgarh whereas maize performs well 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 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 rainfed. Impact of drought is relatively high on productivity of sorghum and peralmillet and low in maize, sesame and groundnut.

**Conclusions**

Following concluions are drawn from the study:

- Wheat cultivation could be continued in Bhilwara district with adoption of improved varieties (drought tolerant).
- Large area of the district is reported to contain higher 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 irrigations 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.
- 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.

- The pulse crops 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).
- 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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