Ann. Agric. Res. New Series Vol. 46 (4) : 441-446 (2025)

Current and potential soil suitability of barley for crop diversification in IGP region of India: a case study

Ashok Kumar[1]* Vikas Joon[1], Ritu Nagdev[1] and Jaya N. Surya[1]

[1]*ICAR-National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), Regional Centre, Delhi, IARI Campus, New Delhi-110 012, India*
**Corresponding Author's Emails: ashok_nbss@yahoo.com; Ashok.Kumar42@icar.org.in*

Received: September 2025; Revised Accepted: December 2025

Abstract

Soil resources of the study area were evaluated for current and potential soil suitability of barley under existing soil-site regime. Current soil suitability (actual suitability) revealed that 44121.0 ha area evaluated to be highly suitable (S1), whereas remarkable increase (22.9%) in S1 areas has been observed under potential soil suitability regime. Moreover, maximum acreage found to be moderately suitable (S2) for barley production under both current and potential suitability evaluation scenario. Potential soil suitability evaluation recorded significant increase in class S2 area (45.0%) over the existing acreage. The study identified the production constraints and suggested need based intervention including the apt agronomic measures to ensure best utilization of marginally suitable (S3) and presently unfit areas (N1) in due course of time. LMUs based soil management strategies, land evaluation enabled crop planning, and integrated approaches for nutrient and water management, application of soil amendments such as gypsum in salt-affected areas and farm forestry practices need to be included in the research and policy domains to ensure efficient utilization of land resources for sustainable barley production in the study area of IGP region.

Key words: Alternate land use option, Barley, Current and potential soil suitability, Diversification, IGP

Introduction

Barley (*Hordeum vulgare* L. 2n=14) is one of the earliest domesticated crop species in the world which, found to be cultivated about 17,000 years ago in the Nile River Valley of Egypt (Purugganan *et al*., 2009). Globally, it is being cultivated in more than 100 countries, and considered as the fourth most important cereal crop after wheat, rice, and maize (Giraldo *et al*., 2019). In India, it is largely grown in the states of Rajasthan, Uttar Pradesh, Haryana, Punjab, Madhya Pradesh, Uttarakhand, Himachal Pradesh, Bihar, Jammu and Kashmir, West Bengal, Chhattisgarh, and Sikkim (Jan *et al*., 2022). Barley cultivation is gaining currency due to its nutritional and nutraceutical properties besides, its uses as food, feed, and for making malt and barley tea (Raj *et al*., 2023). It is rich source of phytochemicals such as β-glucan, phenolic acids, flavonoids, lignans, tocols, phytosterols, and folate. Thus, its whole grain consumption decreases the risk of chronic illnesses such as diabetes, cancer, obesity, and cardiovascular disease (Geng, 2022). Barley crop gives rise hope to the food industry for developing sustainable and affordable products to address health issues such as cancer, heart disease, and many emerging health issues. It is best known examples of cereal-based functional foods beside others such as oats, sorghum, millet, and wheat (Das *et al*., 2023). Barley is often described as poor man's crop due to low input requirement and better adaptability to marginal lands, temperate and sub-tropical climates as well as understressed environmental con-

ditions *viz*., drought, salinity and alkalinity (Pardo *et al*., 2022). Further, its outstanding ability to withstand adverse climatic conditions it is considered as best alternate land-use option for food security (Lal, 2005). Such climate-change-induced impacts can be addressed by employing improved soil and crop management practices (Roberts and Mattoo, 2018). However, the scope of soil and crop management practices is being limited by various kinds of land/soil degradation, which negatively impacts the crop productivity, food and livelihood security (Bhattacharyya *et al*., 2015). In such circumstances, land evaluation strategy seems to be the ideal solution to address the issues of soil-site limitations for a particular alternate land use option and to ensure sustainable crop production (Kumar *et al.*, 2022; Nagdev *et al*., 2024).

In view of the above, a case study was undertaken in the Indo-Gangetic Plain (IGP) region by taking Mathura district of Uttar Pradesh, India to evaluate the current (actual) and potential soil suitability of barley as an alternate land use option for crop diversification. The study depicted suitable areas for barley cultivation through maps generated under Geographic Information Systems (GIS) environment (Bagherzadeh and Mansouri Daneshvar, 2011). The present study is of immense usefulness to the researchers, administrators, and policy planners to develop site-specific strategies for sustainable barley production.

Materials and Methods

The study was carried out during 2019-20 to 2023-24 in Mathura district of Uttar Pradesh, India. The study area falls under upper Indo-Gangetic Plain (IGP) region of IGP spanning over 3340 square kilometers and is located between 27°13′ 35" to 27°57′24" N Latitudes and 77°16′35" to 77°59′16" E Longitudes. Climate of the study site is characterized by hot dry semiarid climate with hot summers and cool winters. The long term climate data (rainfall and temperature) since, 1991-2021 were used as site characteristics for evaluation of current and potential soil suitability of barley. The study area is more or less plain and comes under Yamuna river alluvium (fluvial and alluvial deposits) composed of unconsolidated beds of sand, silt and clay and their mixture in varying proportions, and a stretch of the hillocks of Aravalli range. The soil resources (1:50,000 scale) of the study area were delineated into 8 LMUs. The land suitability evaluation for barley was carried out following FAO guidelines for land evaluation (FAO, 1976) and Sys *et al.* (1993). The current suitability (also known as actual soil suitability) and potential soil suitability for barley crop were evaluated following Kumar *et al.* (2020). The soil suitability maps of barley were generated in the GIS environment using ArcGIS software version 10.3.1.

Results and Discussion

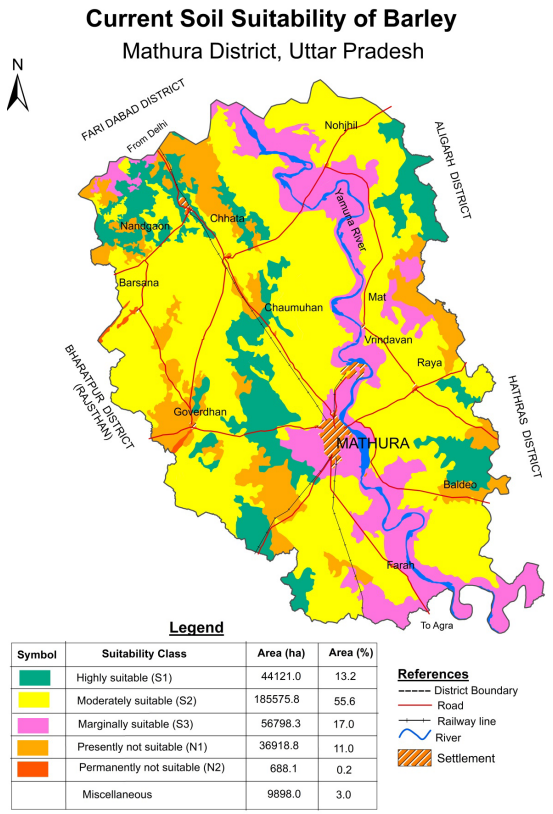
Current (actual) soil suitability of barley

Current soil suitability is also known as actual soil suitability refers to the evaluation of soil suitability for a particular land use within the existing soil-site regime. It denotes the actual area available in a particular class for certain land use under existing limitations such as drainage/permeability, organic carbon content, soil pH, and CEC (Table 1). Manrique and Uehara (1984) also highlighted that the improved soil management plays vital role in enhancing the soil qualities to meet the crop/crops requirements for example, improvement in soil suitability class assigned as marginal or not suitable. The current soil suitability evaluated maximum study area (185575.8 ha) under moderately suitable class (S2) followed by highly suitable class (S1) area (44121.0 ha), and 36918.8 ha categorized as presently unfit (N1) for barley cultivation (Fig. 1). Presently not suitable (class N1) area is largely due to high soil pH conditions of LMU6 and LMU7. Further, drainage is a cause of concern for sustainable crop production in the cultivated LMUs (LMU1 and LMU6) and also in the LMU8 (uncultivated) while, organic carbon status evaluated to be low in the entire study area. The study findings are in coherence with previous studies which, exhort upon the addition of OM to achieve the optimum drainage status and gypsum to improve the soils' physico-chemical properties and as a result help to improve the soil suitability (Hu *et al*., 2005; Yazdanpanah *et al*., 2016; Temiz and Cayci, 2018).

Potential soil suitability of barley

Potential suitability evaluates the potential

land areas likely to be available for specified land uses in due course of time with the improved scientific interventions that addresses the existing soil-site limitations with best management practices. The soil-site limitations for barley cultivation in LMU1 for example, include texture, slope, drainage, organic carbon, soil pH, and CEC (Table 1). Like current suitability, potential soil suitability also evaluated maximum study area (269170.6 ha) under moderately suitable class (S2) followed by highly suitable class (S1) area (54243.3 ha) (Fig. 2). The increase in class S2 area is largely due to improved management practices that have led to rectification of existing moderate limitations in various LMUs. Adoption of best agronomic management measures counter the limitations and brought the marginally suitable areas (S3) to class S2. The changes in current soil suitability to potentially suitable areas revealed significant increase in the class S1 areas to the tune of 22.9% over the actual suitable areas (Fig. 3). Likewise, class S2 areas also showed significant increase



Symbol	Suitability Class	Area (ha)	Area (%)
	Highly suitable (S1)	44121.0	13.2
	Moderately suitable (S2)	185575.8	55.6
	Marginally suitable (S3)	56798.3	17.0
	Presently not suitable (N1)	36918.8	11.0
	Permanently not suitable (N2)	688.1	0.2
	Miscellaneous	9898.0	3.0

Fig. 1. Current soil suitability map of barley for the study area

Table 1. Current and potential soil suitability evaluation of barley in the study area*

LMUs	Rainfall	Temp.	Depth class (cm)	Texture	Coarse fragments %	Stoniness/ Rockiness	Slope	Erosion	Drainage/ Permeability	OC	$CaCO_3$ in root zone	pH	EC (dSm^{-1})	CEC ($cmol+kg^{-1}$)	BS (%)	ESP (%)	Overall Current Suitability	Overall Potential Suitability
LMU1	S1	S1	S1	S3	S1	S1	S2	S2	S3	S3	S1	S3	S1	S2	S1	S1	S3	S2
LMU2	S1	S1	S1	S3	S1	S1	S1	S1	S1	S3	S1	S3	S1	S2	S1	S1	S2	S2
LMU3	S1	S1	S1	S3	S1	S1	S1	S1	S1	S3	S1	S1	S1	S2	S1	S1	S2	S2
LMU4	S1	S1	S1	S3	S1	S1	S1	S1	S1	S3	S1	S2	S1	S2	S1	S1	S2	S2
LMU5	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S2	S1	S2	S1	S1	S1	S1
LMU6	S1	S1	S1	S1	S1	S1	S1	S1	S2	S3	S1	N1	S1	S2	S1	S1	N1	S1
LMU7	S1	S1	S1	S3	S1	S1	S1	S1	S1	S3	S1	N1	S1	S2	S1	S1	N1	S2
LMU8	S1	S1	S2	N2	S1	N2	N2	N2	N2	S3	S1	S1	S1	S1	S1	S1	N2	N2

*Suitability rating as per matching table criteria (Sys *et al.*, 1993), and Expert Opinion (EO)

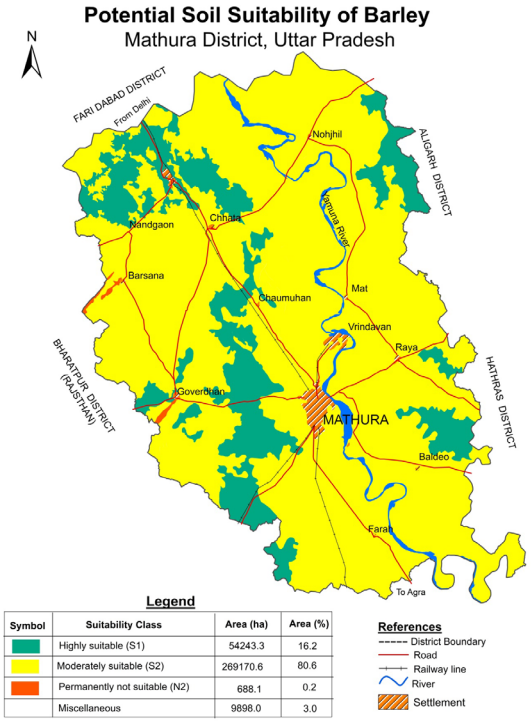
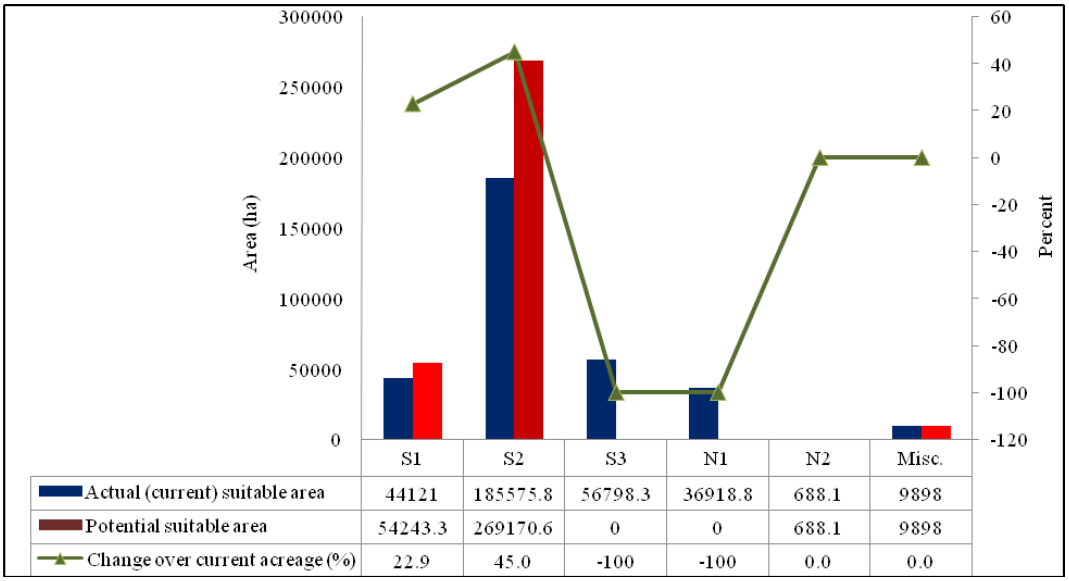


Fig. 2. Potential soil suitability of barley for the study area

(45%) over currently suitable acreage for barley cultivation. The improvement in class S1and S2 areas compensated with a corresponding decline in the marginally suitable (S3) and presently not suitable (N1) areas (Fig. 3). Our study findings are in close agreement with the land/soil suitability evaluated by Abd-Elmabod *et al*. (2019) in terms of their current (scenario) and potential suitability (optimum scenario) for various agri-horticultural land uses.

Conclusion

The study evaluated the current and potential soil suitability for sustainable barley crop production in the upper IGP region of Indo-Gangetic Plains. Suitable areas (highly as well as moderately) offer great scope for its cultivation in the fertile as well as resource constrained, marginally fertile, and water scares agro-ecologies. Potentially suitable areas registered a remarkable improvement in highly suitable (S1) and moderately suitable (S2) areas by 22.9% and 45.0%, respectively over the actual areas available at present in these suitability classes for barley cultivation. Thus, the present study provides valuable insight about optimum utilization of land resources for barley cultivation under existing and improved soil-site regime. The study suggested the prospects of barley, as an alternate land use option, to diversify the rice-wheat agro-ecologies in the IGP region. Further, the study will be of immense usefulness to unveil the appropriate policy measures to improve the existing land utilization and resource use capabilities of the area in a holistic manner.



	S1	S2	S3	N1	N2	Misc.
Actual (current) suitable area	44121	185575.8	56798.3	36918.8	688.1	9898
Potential suitable area	54243.3	269170.6	0	0	688.1	9898
Change over current acreage (%)	22.9	45.0	-100	-100	0.0	0.0

Fig. 3. Study area under different suitability classes for barley cultivation in the current and potential suitability scenario

Acknowledgement

The authors express their sincere thanks to the Director, ICAR-NBSS & LUP, Nagpur, India for financial support during the study.

References

Abd-Elmabod, S. K., Bakr, N., Muñoz-Rojas, M., Pereira, P., Zhang, Z., Cerdà, A., Jordán, A., Mansour, H., De la Rosa, D. and Jones, L. 2019. Assessment of soil suitability for improvement of soil factors and agricultural management. *Sustainability,* **11**: 1588. DOI:10.3390/su11061588.

Bagherzadeh, A. and MansouriDaneshvar, M. R. 2011. Physical land suitability evaluation for specific cereal crops using GIS at Mashhad Plain, Northeast of Iran. *Frontiers of Agriculture in China,* **5**: 504-513. DOI: 10.1007/s11703-011-1102-6.

Bhattacharyya, R., Ghosh, B. N., Mishra, P. K., Mandal, B., Rao, C.S., Sarkar, D., Das, K., Anil, K. S., Lalitha, M., Hati, K. M. and Franzluebbers, A. J. 2015. Soil degradation in India: challenges and potential solutions. *Sustainability,* **7(4)**: 3528-3570. DOI. https://doi.org/10.3390/su7043528.

Das, T., Thakur, R., Dhua, S., Teixeira-Costa, B. E., Rodrigues, M. B., Pereira, M. M., Mishra, P. and Gupta, A. K. 2023. Processing of cereals. *In*: Eds. Gulzar, A. N. et al, 2023. Cereal Grains: Composition, Nutritional Attributes, and Potential Applications. P.354. DOI. 10.1201/9781003252023.

FAO. 1976. A framework for land evaluation. Food and Agriculture Organization of the United Nations. *Soils Bulletin,* **32**. FAO, Rome.

Geng, L., Li, M., Zhang, G. and Ye, L. 2022. Barley: a potential cereal for producing healthy and functional foods. *Food Quality and Safety,* **6:** 1-13, https://doi. org/10.1093/fqsafe/fyac012.

Giraldo, P., Benavente, E., Manzano-Agugliaro, F. and Gimenez, E. 2019. Worldwide Research Trends on Wheat and Barley: A Bibliometric Comparative Analysis. *Agronomy*, **9**: 352. DOI.10.3390/agronomy9070352.

Hu, Z. Y., Zaho, F. J. and McGrath, S. P. 2005. Sulphur fractionation in calcareous soils and bioavailability to plants. *Plant and Soil,* **268**: 103–109. https://doi.org/10.1007/s11104-004-0229-0.

Jan, S., Khan, M. N., Jan, S., Zaffar, A., Rashid, R. Khan, M.A., Sheikh, F. A., Bhat, M. A. and Mir, R. R. 2022. Trait phenotyping and molecular marker characterization of barley (*Hordeum vulgare* L.) germplasm from Western Himalayas. *Genetic Resources and Crop Evolution*, **69**: 661-676. DOI. https://doi.org/10.1007/s10722-021-01251-z.

Kumar, A., Mahapatra, S. K., Ramamurthy, V., Meena, R. K. and Singh, T. 2022. Soil-site suitability evaluation for diversification of rice-wheat cropping system ecology in the Indo-Gangetic Plains of India-A Case Study. *Annals of Agricultural Research New Series,* **43 (4)**: 396-403.

Kumar, A., Singh, D. and Mahapatra, S. K. 2020. Current and potential soil suitability of pearl millet, wheat and mustard for sustainable production in *Aravalli foothills* of Mewat Region of Haryana, India. *International Journal of Current Microbiology and Applied Sciences*, **9**(5): 3566-3583. https://doi.org/10.20546/ijcmas.2020.905.424.

Lal, R. 2005. Climate change and global food security. *In Climate Change, Soil Carbon Dynamics, and Global Food Security*. CRC Press, Boca Raton, FL, USA. pp. 132-162.

Manrique, L. A. and Uehara, G. A. 1984. Proposed Land Suitability Classification for Potato. I. Methodology. *Soil Science Society of America Journal,* **48**: 843-847.

Nagdev, R., Meena, R. K., Kumar, A., Joon, V. and Surya, J. N. 2024. Evaluation of the Suitability of Horticultural Crops under Prevailing Environmental Conditions -A Case Study of Punjab. *Journal of Geography, Environment and Earth Science International*, **28**(11): 90-106.

Pardo, J. J., Domínguez, A, Éllis, B. C., Montoya, F., Tarjuelo, J. M. and Martínez-Romero, A. 2022. Effect of the optimized regulated deficit irrigation methodology on quality, profitability and sustainability of barley in water scarce areas. *Agricultural Water Management*, 266: 107573. DOI. https://doi.org/10.1016/j.agwat.2022.107573.

Purugganan, M. D. and Fuller, D. Q. 2009. The nature of selection during plant domestication. *Nature,* **457**: 843-848. https://doi.org/10.1038/nature07895.

Raj, R., Shams, R., Pandey, V. K., Dash, K. K., Singh, P. and Bashir, O. 2023. Barley phytochemicals and health promoting benefits: A comprehensive

review. *Journal of Agriculture and Food Research,* **14**: 100677. DOI. https://doi.org/10.1016/j.jafr.2023.100677.

Roberts, D. P. and Mattoo, A. K. 2018. Sustainable agriculture-Enhancing environmental benets, food nutritional quality and building crop resilience to abiotic and biotic stresses. *Agriculture,* **8(1)**: 8. DOI. https://doi.org/10.3390/agriculture8010008.

Sys, C., Van Ranst, E., Debaveye, I. J. and Beernaert, F. 1993. Land evaluation part III: Crop requirements. General administration for development cooperation, Agricultural publication No. **7**. Brussels-Belgium, 199.

Temiz, C. and Cayci, G. 2018. The effects of gypsum and mulch applications on reclamation parameters and physical properties of an alkali soil. *Environmental Monitoring and Assessment,* **190**: 347. DOI: 10.1007/s10661-018-6669-4.

Yazdanpanah, N., Mahmoodabadi, M. and Cerdà, A. 2016. The impact of organic amendments on soil hydrology, structure and microbial respiration in semiarid lands. *Geoderma,* **266**: 58-65. DOI. https://doi.org/10.1016/j.geoderma. 2015.11.032.