Land suitability analysis for Mango using AHP method

Sanjani Salunkhe (sanjanisalunkhe@gmail.com)
CAET, Dr. B. S. K. K. V
Sachin Nandgude
Dr. A. S, CAET, MPKV
Harshal Bhange
CAET, Dr. B. S. K. K. V

Research Article

Keywords: AHP, GIS, Land suitability, MCDM

Posted Date: July 5th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1781790/v1

Abstract

The present study determined the mango land suitability in Ratnagiri district with combine use of MCDM with GIS based AHP. There were five main criteria i.e. climate, topography, soil, erosion and conservation measures and eleven sub-criteria were used in the present study. The all main criteria maps were prepared in ArcGIS according to mango crop requirement. After preparing the various thematic maps, AHP process has been used to calculate the weights through pairwise comparison matrix. In order to accept the weighting results or judgments, a consistency ratio (CR) value was calculated to determine whether the pairwise comparison was consistent. Then the 'Weighted Overlay' tool in overlay toolset which is in spatial analyst tools in ArcGIS has been used to perform an overlay analysis. The results showed that 16.86 percent of the area was classified as highly suitable, while 67.93 percent, 10.03 percent, and 5.18 percent of the area were classified as moderately suitable, marginally suitable, and not suitable, respectively. As a result, a GIS-based AHP approach can provide better insights for improving capabilities and producing more realistic output scenarios.

Introduction

Soil erosion is a major issue all over the world. Global land resource demand is increasing as the world's population grows and prospers, but soil and agricultural land health and productivity are declining (Montanarella et al. 2016). In India, approximately 53% of total land area is prone to erosion, with an estimated 4.87 billion tons of soil being detached annually (Mandal et al. 2020). The amount of soil erosion in Maharashtra per year is approximately 773.5 M tonnes (Durbude 2015). The annual soil erosion in the Konkan region is 119.84 million tonnes (Nandgude et al. 2018).

Regional spatial and quantitative soil erosion information helps to prepare for restoration, erosion control and environmental management. It is essential to determine erosion prone areas with greater accuracy. The combination of geospatial technologies and erosion models, such as USLE, has proven to be an effective method for estimating erosion magnitude and spatial distribution (Parveen and Kumar 2012). Accelerated soil erosion is also contributing to an increase in greenhouse gas emissions and carbon addition to the atmosphere. Carbon sequestration is one of the most prudent methods of reducing GHG emissions. Carbon sequestration is the process by which atmospheric carbon dioxide (CO_2) is absorbed by trees, plants, and crops and stored as carbon in biomass such as tree trunks, branches, foliage, roots, and soils via photosynthesis (Patil and Kumar 2017).

Land evaluation is foundation of planning and management for sustainable land resources and it helps to know whether the land resources are degraded or quality is improved (Mohana et al. 2009). It is prediction of land quality for a specific use on the basis of its productivity, risk of land degradation and required management (Bunruamkaew and Murayam 2011). The principal objective of multi-criteria is to study a variety of alternatives for multiple criteria and competing goals approaches for decision-making. While MCDM was developed as a technique to deal with instability at various stages of decision-making, it has become highly sophisticated to integrate the views, thoughts, and concerns of stakeholders and some concerns about its transparency to the end user (Ananda and Herath 2003; Hajkowicz and Donald 2006). One of the most widely used MCDM techniques in GIS-based suitability procedures is the Analytical Hierarchy Process (AHP) because of its suitability for making decisions based on multiple factors rated according to experts preferences (Din and Yunusova 2016; Qureshi et al. 2018). It calculates the weight of importance for various land uses using a pairwise comparison of various parameters of factors based on their relative importance (Pramanik 2016). As a result, in integrating local requirements and conditions into final decisions, a study of land suitability must be conducted (Prakash 2003).

In terms of both area and production, India is the world's largest mango producer and one of the world's leading mango producers. In Maharashtra, mango covers approximately 4.82 lakh ha, with an annual production of 6.33 MT and a productivity of 1.3 MT/ha (Anonymous 2015a). Mango cultivation occupied 1.10 lakh ha of productive land in Konkan, producing 2.6 lakh MT per year. As a result, Konkan Mango productivity ranges between 2.5 and 3.0 MT/ha, which is roughly three times lower than the national average (Anonymous 2015b).

Mango is an important perennial fruit crop in Maharashtra's Konkan region. The Konkan region of Maharashtra is endowed with abundant natural resources such as soil, water, and vegetation. However, its vulnerability in the form of a biodiversity hotspot (Chitale et al. 2015) is well known due to extreme weather conditions and undulating terrain. This results in significant soil and water loss due to runoff. Improper use of land and water resources, as well as soil erosion and runoff, deplete the soil carbon pool, reducing soil fertility and quality and increasing the degradation of land resources. The lack of appropriate soil and water management practices is responsible for the overall decline in land productivity. As a result, land suitability assessment is required in the Konkan region. However, the primary goal of this study was to assess mango crop suitability using AHP in GIS.

Study area:

This research was carried out in the Ratnagiri district of Maharashtra's Konkan region. It extends for 180 kilometres north to south and 64 kilometres east to west. Ratnagiri district covers an area of 8,459 sq. km. It was divided into 5 watersheds and received 3,591 mm of average rain per year (Fig. 1).

Data collection:

The various land characterization parameters influencing mango crop production were chosen based on crop experts and available mango crop requirement information from various literatures. As a result, five major criteria for mango land suitability were used, including climate, topography, soil, erosion risk, and conservation measures, etc. Table 1 summarizes the detail information from various data sources used for mango land suitability.

Material And Methods

Selection of evaluation criteria

The criteria were evaluated using similar types of other location cultural practices, crop experts, and information about Mango crop requirements from reviewed literature. Table 2 shows the five main criteria and eleven sub-criteria used in the study for Mango crop suitability, which influence Mango crop production.

Analytical hierarchy process (AHP)

In this study, the Analytical hierarchy process (AHP) method based on GIS was used to assess mango land suitability. AHP was developed by Saaty (1977) with comparison of two elements is derived from their relative importance. It uses a pairwise comparison matrix to compute weight values for criteria maps.

Development of pairwise comparison matrix

Saaty and Vargas (1991) proposed a comparison scale ranging from 1 to 9 that describe the degree of importance to each other. Table 3 shows the relative importance of two elements on a scale. This scale was developed to assess the various factors that influence mango production. The weights of the criteria used to evaluate mango suitability were determined using professional experiences of local experts and scientific literature.

Assessing the weights

There must be an evaluation that ranks the relative importance of the criteria in land suitability analysis (Elaalem 2012; Rabia and Terribile 2013). According to Lupia (2014), weighting in land suitability analysis for agricultural crops is intended to express the importance of each factor relative to the effects of other factors that affect crop yield and growth rate. In the current study, professional experiences of local expert opinions were used to decide the ranks of influencing criteria, and weights were determined using a pairwise comparison matrix. The pairwise comparison analysis assists decision makers in determining the relative importance of various factors involved in land suitability (Elaalem 2012). As a result, in the current study, a pairwise comparison matrix was utilized to identify the weights of parameters based on the AHP.

Consistency checking

The consistency of judgments of ranking the criterion influences the accuracy of the calculated weights by pairwise comparison matrix. The Consistency Ratio (CR) measures logical inconsistency in judgments and assisting to identification of potential errors (Cengiz and Akbulak 2009). CR determines how much variation is acceptable in reasonable results, and it is generally expected to be 10% or less for AHP to continue, or derived weights can be used (Rad and Haghyghy 2014). As a result, the consistency ratio was calculated as follows:

$$CI = \frac{(\lambda max - n)}{(n-1)} \quad \ldots\ldots. (1)$$

in which, λmax i. e. maximum Eigen value was calculated by multiplying each weight with its corresponding column total, for example

$$\lambda\, max = (w_1 * \sum_{i=1}^{n} a_{ij}) + \cdots n \quad \ldots\ldots. (2)$$

$$CR = \frac{CI}{RI} \quad \ldots\ldots. (3)$$

Where, λmax is the maximum eigen value, CI is the consistency index, CR is the consistency ratio, RI is the random inconsistency index and n is the numbers of criteria or sub-criteria in each pair-wise comparison matrix (Baniya 2008). The random inconsistency index (RI) is proportional to the number of elements being compared (Saaty 1980).

Standardization of the criteria map

Each evaluation criterion is represented by a map, with ordinal values (such as S1, S2, S3, N) indicating the degree of suitability with respect to a criterion based on crop requirements (Sehgal 1996). These classes must be rated in order to determine how important they are in relation to one another in terms of a specific criterion that contributes to the overall goal. The pairwise comparison technique was used in the study to rate or standardize these values. In addition, criteria were standardized by using the reclassify spatial analyst tool to ensure that each criterion had an equal measurement basis. The five main criteria used in this land suitability analysis were climate, topography, soil, erosion hazard, and conservation measures. Land suitability orders indicate whether or not the land under consideration is suitable. There are two orders: S (suitable) and N (inappropriate) (FAO 1976). Each watershed in Ratnagiri district was classified as highly suitable (S1) class, moderately suitable (S2) class, marginally suitable (S3) class, not suitable (N) class.

The ArcGIS tool was used to create these various data maps, such as maps of soil texture, temperature, and so on, based on the suitability requirements for the mango crop. All five layers of data (soil, climate, topography, erosion hazard, and conservation measures) were overlaid to create the overall suitability map for Mango. The weighted overlay tool in ArcGIS was used to create a suitability map for the mango crop. For each watershed in Ratnagiri district, specific areas were identified under each class of suitability, i.e. S1, S2, S3, N.

Results And Discussion

Evaluation of Criteria Maps

Variation in temperature

The daily minimum and maximum temperatures (Tmin and Tmax in °C) of 11 stations in Ratnagiri district were analyzed from 1988 to 2017 (30 years). Winter season of Konkan region play an important role in initiation of flowering. In present study, the Tmin during flowering stage of mango crop varied between 9.01 °C to 24.19 °C with mean minimum temperature of 18.82 °C. Similarly, Tmax for flowering stage of Mango crop varied between 26.33 °C to 37.23 °C with mean maximum temperature of 32.43 °C.

In Konkan, summer starts from mid of March and lasts till the onset of monsoon. In Ratnagiri district, mean temperature from March to May ranging from 24°C to 32.5°C. Rarely it crosses 34°C in month of May only (Burondkar et al., 2018). It was observed that average mean maximum temperature in Ratnagiri district is gradually increasing from 32.5°C to 32.9°C in month. Thus, in the present study Tmin during fruit growth/harvesting stage of mango crop varied between 11.46 °C to 27.97 °C with mean minimum temperature of 21.37 °C. Similarly, Tmax during fruit growth/harvesting stage of Mango crop varied between 28.87 °C to 45.68 °C with mean maximum temperature of 34.88 °C.

In present study, Tmin for vegetative growth stage of mango crop varied between 17.81 °C to 27.84 °C with mean minimum temperature of 23.40 °C. Similarly, Tmax for vegetative stage of Mango crop varied between 24.74 °C to 39.43 °C with mean maximum temperature of 28.93 °C.

The mean minimum temperature between 13 to 17°C is highly suitable while 17 to 20°C is moderately suitable during flowering growth stage of mango crop in Ratnagiri district (expert's opinion). Thus, classified mean minimum temperature map shows that 80 % area was highly to moderately suitable for flowering growth stage of mango crop in Ratnagiri district. Nearly about 19.90 % of the area was marginally suitable, with no area under not suitable class. Similarly, mean maximum temperature between 30 to 32°C is moderately suitable while 32 to 35°C is marginally suitable during flowering growth stage of mango in Ratnagiri district (expert's opinion). Thus, classified mean maximum temperature map shows that whole Ratnagiri district is moderately to marginally suitable during flowering growth stage of mango crop.

The mean minimum temperature between 20 to 22°C is highly suitable while 22 to 23°C is moderately suitable during fruit/harvesting growth stage of mango crop in Ratnagiri district (expert's opinion). Thus, the mean minimum temperature, 75.86 % of area was highly suitable for fruit/harvesting growth stage of mango crop in Ratnagiri district. Similarly, the mean maximum temperature, 14.17 % of the area under highly to moderately suitable class during fruit growth stage of mango crop in Ratnagiri district. The mean minimum temperature, 36.55 % of the area was moderately suitable during vegetative growth stage of mango crop in Ratnagiri district. Similarly, the mean maximum temperature, almost 97 % of the area was highly suitable for vegetative growth stage of mango crop with temperature varied between 25 to 30°C. Only 2.82 % of the area is marginally suitable.

Spatial variation in rainfall

The amount and distribution of rainfall both are critical in mango production. Despite the fact that mango grows in both low and high rainfall (2500-3000 mm) areas, rainfall during fruit development and maturity can be harmful, causing fruit quality to deteriorate and increasing disease and insect hazards. The Konkan region receives 2500-3500 mm of rain per year. After the rainy season, the temperature rises with more daylight hours from October to November. It possesses the floral induction stress. The analysis of daily rainfall for each Tahsil in Ratnagiri district from 1998 to 2018 (21 years) revealed that the spatial distribution of rainfall in the region is highly suitable for mango.

Mango climate suitability map

Climate potential map for mango crop production produced by overlaying sub-criteria maps of rainfall and temperature (Tmax and Tmin). Using Analytical Hierarchical Process (AHP) approach, temperature (Tmin and Tmax) and rainfall were rated using pairwise comparison method which resulted in weights between 0 to 100. The result shows that Tmin temperature is the most important an influence of 63 % was given in Table 4.

According to the results, only 4.68 percent of the area was classified as highly suitable, 78.33 percent as moderately suitable, and 16.99 percent as marginally suitable for mango production (Fig. 2).

Spatial variation in soil texture

Mango cultivation requires well drained soils. In India, mango grown in lateritic (Alfisols, Ultisols, and Inceptisols), alluvial, kankar and other types of soil. Mango production grows best on the ferruginous red soils of Dharwad and Belgaum (Karnataka), Ratnagiri (Maharashtra), and Goa (Bhattacharyya et al., 2018). The fertility of soil depends on chemical and physical characteristics of soil. So, red loamy soils of Ratnagiri district are suitable for mango growth.

Soil texture prepared from analysis of soil samples from 258 locations in study area. The results indicated that about 53 % area is highly suitable (loamy sand) and 42.40 % is moderately suitable (sandy loam and sandy clay loam) for mango cultivation. Also, only 4.66 % area, which has sandy texture class, is not suitable for mango cultivation.

Spatial variation in organic carbon

In general, mango soils in Konkan region of Maharashtra are rich in organic carbon. Organic carbon in study area was ranging from 0.60 % – 2.69 % indicating that soils are 'very high' in organic carbon. In general organic carbon content in lateritic soils of Konkan is in 'very high' as per ratings proposed by Bangar and Zende (1978). The results indicated that, 100 % area comes under the category of highly and moderately suitable as per as availability organic carbon in soils of study area. Similar studies in the past have also shown 'very high' organic carbon in mango orchards of Ratnagiri district (Pereira et al. 1986; Mahajan 2001; Suryavanshi 2010; Joshi 2012).

Spatial variation in bulk density

Bulk density is the indirect indication of soil compaction, soil health and good drainage. It influences infiltration, rooting depth, available water capacity, soil porosity and plant nutrient availability. Bulk density values indicates that, most of the mango soils in Maharashtra in Konkan falls within the range of 1.1 – 1.6 which supports good drainage. In present study, bulk density of soil samples was determined in the soil testing laboratory of Department of Soil Science and Agricultural Chemistry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri by using "Soil clod" method. The bulk density map shows that, 100% area was highly suitable for mango crop in Ratnagiri district.

Mango soil suitability map

The soil potential map for mango production produced by overlaying sub-criteria maps for soil texture, organic carbon and bulk density. Using AHP approach, result shows that soil texture is most important an influence of 54 % was given in Table 5.

According to the results, approximately 52.92 percent of the area in Ratnagiri district was classified as highly suitable, 42.44 percent as moderately suitable, and 4.64 percent as not suitable for mango production (Fig. 3).

Spatial variation in slope

Slope has a strong effect on cultivation of crops. Slope land is an important factor in mango crop growth and development. The results revealed that about 66 % of the area is under the category of highly to moderately suitable class with slope ranging from 8 to 16%, which is suitable for mango cultivation (Fig. 4). Because of the very high slope (more than 30 %) approximately 10.76 percent of the land is unsuitable for mango cultivation. Hence, the not suitable area was concentrated in eastern part of the mountains and hills of Ratnagiri district.

Spatial variation in soil loss

Mango crops in India are observing severe degradation of soil. Orchard management practices like repeated ploughing that destroys the soil structure and degrades organic matter, burning or removing crop residues from the orchards, mono-cropping with single variety. Erosion can degrade soil structure, reduces water holding capacity, reduces soil nutrient contents, and reduce the effective rooting depth, ultimately it reduces soil productivity (Tenberg et al. 2014; Valera et al. 2016). The annual soil loss of study area was calculated by using USLE. According to the findings, approximately 42 percent of the area falls into the category of highly suitable to moderately suitable. About 36.41 % of the area is not suitable of mango cultivation as this area has very severe soil loss (more than 40 t/ha/yr soil loss class). Thus, it is essential to adopt various conservation measures to reduce soil loss, so that not suitable area will be converted to suitable land for mango cultivation.

Spatial variation in carbon loss

Globally, accelerated soil erosion is one of the severe environmental problems, which causes heavy loss of soil organic carbon. There is a great consideration about the outcome of eroded carbon (C-erosion) and whether the net effect of erosion on the carbon (C) cycle is to act as a C source. Mineralization of eroded C depends upon temperature, oxygen supply, water supply and decomposition of agents to organic matter (Dungait et al. 2012). In the present study, carbon loss through soil loss was determined for specific erosion category in t/ha/yr. Carbon loss (C-loss) is estimated as a function of erosion rate, soil organic carbon concentration, and Carbon Enrichment Ratio (CER) values (Mandal et al. 2020). Carbon loss is product of the soil loss, SOC content and carbon enrichment ratio (CER) values. C-erosion rate was estimated using the formula,

$$\mathrm{C-erosion\ (t/ha/yr)} = \frac{\mathrm{(soil\ loss\ (t/ha/yr) * SOC\ (\%) * CER)}}{100}$$

\

Where, soil loss is the erosion rate (t/ha/yr), SOC is the concentration of SOC (%) and CER is the carbon enrichment ratio. Mandal et al. (2020) presented the state wise CER values for various erosion classes. The results show that approximately 54.39 percent of the area is highly suitable to moderately suitable for mango cultivation, while 22.64 percent of the area is not suitable for mango cultivation due to severe carbon loss. Thus, it indicates that as soil erosion rate increases, carbon loss also increases, following a similar trend as soil loss. Hence, by adopting conservation measures, it reduces both soil loss and carbon loss, which improves the mango productivity.

Mango erosion hazards suitability map

The erosion hazard potential map for mango production produced by overlaying sub-criteria maps for soil loss and carbon loss. Using AHP approach, result shows that soil loss is most important an influence of 75 % was given in Table 6.

The results show that approximately 24.48 percent of the area in Ratnagiri district was classified as highly suitable, 21.24 percent as moderately suitable, 19.27 percent as marginally suitable, and 35.01 percent as not suitable for mango production (Fig. 5).

Soil and water conservation measures

Soil and water conservation measures enhance the productivity of mango. Soils are the vital part of the long-term solution to enhance mango productivity. In present study various soil and water conservation measures (SWC) are recommended as per climatic and topographic criteria. The SWC measures shows that, 22 % area was highly to moderately suitable for mango crop. About 4.75 % area under permanently not suitable as it includes the waterbody, built up, stony or rocky areas. Similarly, about 71.17 % of area was under currently not suitable. This land has not recommended any soil and water conservation measures as per suitability criteria. Mountains and hills with very steep slope more than 20 % covered about 24.78 % of the study area. This steep slope land is not suitable for mango cultivation and is also most susceptible to soil loss. About 36.41 % of the study area experienced very severe erosion. Thus, this land is currently not suitable but it can be converted to suitable by management techniques. Such as, nutrient management, if the appropriate soil depth is not available then it is necessary to add the soils to make it suitable soil depth for cultivation. Thus, it can say that only 24 % area could brought under soil and water conservation measures which is suitable for mango cultivation.

Carbon Sequestration

Carbon sequestration rates differ depending on the tree species, soil type, regional climate, topography, and management practices. Fruit crops are seen as an alternative way to help and solve the effects of forest depletion caused by forest degradation and deforestation in order to replace the lost forest and increase the reservoir base for carbon sequestration. Because mango is India's most important fruit crop and occupies the most land under fruit crops, the ability of mango plantations to sequester carbon requires special attention. The carbon sequestration shows that, 29.95 % area was highly suitable for mango crop with moderately and marginally suitable as 1.36 % and 10.81 % respectively. Similarly, about 53.13 % of the area was under currently not suitable. This currently not suitable land can be converted to suitable by using various management techniques which improve the carbon sequestration. The technique such as use of cover crops, mulching/residue management which improves soil moisture, reduce the soil erosion as well as carbon loss, increase the soil organic carbon, ultimately enhanced the mango productivity and profitability.

Mango conservation measure suitability map

The conservation measure potential map for mango crop production produced by overlaying sub-criteria maps for conservation measure and carbon sequestration. Using AHP approach, result shows that conservation measures are most important an influence of 67 % was given in Table 7.

The result shows that about 16.54 % area was under highly to moderately suitable, 17.14 % area under marginally suitable and 66.32 % area under currently not suitable for mango production in Ratnagiri district (Fig. 6).

Overall land suitability map using main criteria for mango

The final potential map for mango crop production produced by overlaying main criteria suitability maps (climate, soil, slope, conservation measure and erosion) using weighted overlay technique in ArcGIS. AHP was used to estimate the weights of each main criterion which showed that experts consider soil is most important with an influence of 50 % was given in Table 8.

The result shows that about 84.76 % area was under highly to moderately suitable, 10.03 % area under marginally suitable and 5.18 % area under currently not suitable for mango production (Fig. 7).

Conclusion

The current study evaluated land suitability for mango crop in the Ratnagiri district. Five main criteria were used to evaluate mango land. According to the AHP method results, the soil parameter is the most important factor, followed by slope, soil loss, climate, and conservation measures. According to the findings, approximately 84.76 percent of the area was classified as highly to moderately suitable for mango cultivation. As a result, the GIS-based AHP MCDM method was observed to be incredibly helpful in incorporating soil, slope, soil loss, climate, and conservation measures parameters for land suitability evaluation in the study.

References

1. Ananda J, Herath G (2003 The use of Analytic Hierarchy Process to incorporate stakeholder preferences into regional forest planning. Forest policy and economics 5 (1): 13 – 26.
2. Anonymous (2015a) Indian Horticulture Database of National Horticulture Board: 3 – 9.
3. Anonymous (2015b) Report submitted by Joint Director of Agriculture, Konkan division, Dept. of Agril. Thane during Kharif Review Meeting.
4. Bangar A, Zende G (1978) Soil Testing: A new basis for efficient fertilizer use. J. Maharashtra Agric. Univ., 3(2): 81 – 84.
5. Baniya N, (2008) Land suitability evaluation using GIS for vegetable crops in Kathmandu valley/Nepal (Doctoral dissertation, Humboldt-University zu Berlin).
6. Bhattacharyya T, Patil K, Kasture M et al (2018) Advances in Mango production technology (Chapt. 4). Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri (Maharashtra), 71 – 98.
7. Bunruamkaew K, Murayam Y (2011) Site suitability evaluation for ecotourism using GIS and AHP: A case study of Surat Thani province, Thailand. Procedia-Social and Behavioral Sciences 21: 269 – 278.
8. Burondkar M, Kulkarni M, Salvi B et al (2018) Mango: An Economic Pillar of Konkan Region of Maharashtra. Advanced Agricultural Research and Technology Journal, 2(2): 160 – 170.
9. Cengiz T, Akbulak C (2009) Application of analytical hierarchy process and geographic information systems in land-use suitability evaluation: a case study of Dumrek village. Int. J. Sustain. Develop. World Ecol., 16 (4): 286 –294.
10. Chitale V, Behera M, Roy P (2015) Global biodiversity hotspots in India: significant yet under studied. Current Science 108(2).
11. Din G, Yunusova A (2016) Using AHP for evaluation of criteria for agro-industrial projects. International Journal of Horticulture and Agriculture 1(1): 6.
12. Durbude D (2015) Hydrological impact assessment of SWC measures in Ralegon Siddhi model watershed. Indian Journal of Soil Conservation 43(3): 197–203.
13. Dungait J, Hopkins J, Gregory N, Whitmore A (2012) Soil organic matter turnover is governed by necessibility not recalcitrance. Global Change Biology 18: 1781–1796.

14. Elaalem M (2012) Land suitability evaluation for sorghum based on boolean and fuzzy-multi-criteria decision analysis methods. International Journal of Environmental Science and Development 3(4): 357– 361.
15. FAO (1976) A framework for land evaluation: soils bulletin 32. Food and Agriculture Organization of the United Nations, Rome
16. Hajkowicz S, Mc Donald G (2006) The assets, threats and solvability (ATS) model for setting environmental priorities. Environmental policy and planning 8(1): 87 – 102.
17. Joshi N (2012) Micronutrients status of soil from Mango orchards of Ratnagiri district and their relationship with soil properties. M. Sc. Thesis submitted to Department of Soil Science and Agricultural Chemistry, Dr. B. S. K. K. V. Dapoli.
18. Lupia D (2014) Crop/land suitability analysis by ArcGIS tools. Technical report.
19. Mahajan T (2001) Status and distribution of micronutrients in relation to the properties of lateritic soils under mango orchards in South Konkan. M.Sc. (Agri.) Thesis submitted to Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra.
20. Mandal D, Giri N, Srivastava P (2020) The magnitude of erosion-induced carbon (C) flux and C-sequestration potential of eroded lands in India. European Journal of Soil Science 71: 151 – 168.
21. Mohana P, Mariappan N, Manoharan N (2009) Land suitability analysis for the part of Parambikulam Aliyar command area, Udumalpet Taluk using remote sensing and GIS Techniques. International Journal on Design and Manufacturing T Echnologies 3(2): 98 – 102. doi:10.18000/ ijodam.70069
22. Montanarella L, Pennock D, McKenzie N et al (2016). World’s soils are under threat. Soil 2: 79 – 82.
23. Nandgude S, Mahale D, Jagtap D et al (2018) Natural Resources Atlas of Konkan, book published by DBSKKV, Dapoli, Maharashtra.
24. Parveen R, Kumar U (2012) Integrated Approach of Universal Soil Loss Equation (USLE) and Geographical Information System (GIS) for Soil Loss Risk Assessment in UpperSouth Koel Basin, Jharkhand. Journal of Geographic Information System (4): 588 – 596.
25. Patil P, Kumar A (2017) Biological carbon sequestration through fruit crops (perennial crops - natural “sponges” for absorbing carbon dioxide from atmosphere). Plant Archives 17(2): 1041 – 1046.
26. Prakash T (2003) Land suitability analysis for agricultural crops: a fuzzy multi-criteria decision making approach. ITC (Master’s thesis).
27. Pereira A, Chavan A, Varade P (1986) Physico-chemical properties and micronutrients status of the mango orchard hill soils of Konkan. J. Maharashtra Agric. Univ., 11(2): 134 – 136.
28. Pramanik M (2016) Site suitability analysis for agricultural land use of Darjeeling district using AHP and GIS techniques. Modeling Earth Systems and Environment 2(2): 56.
29. Rabia A, Terribile F (2013) Introducing a new parametric concept for land suitability assessment. Int. J. Environ. Sci. Develop. 4 (1): 15 – 19.
30. Rad L, Haghyghy M (2014) Integrated analytical hierarchy process (AHP) and GIS for land use suitability analysis. World Applied Sciences Journal 32(4): 587 – 594.

31. Saaty T (1977) A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology 15(3): 234–281.
32. Saaty T (1980) The Analytic Hierarchy Process: New York, NY, McGraw Hill, reprinted by RWS Publication, Pittsburgh.
33. Saaty T, Vargas L (1991) Prediction, projection and forecasting. Kluwer Academic Publishers, Dordrecht.
34. Sehgal J (1996) Pedology: concept and applications. New Delhi, Kalyani Publishers.
35. Suryavanshi A (2010) Micronutrient status and it's relationship with soil properties in mound planted mango orchards of Sindhudurg district (Konkan region, M.S.). M.Sc. (Agri.) Thesis submitted to Balasaheb sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri,Maharashtra.
36. Tenberg A, Da, V, Dechen S, Stocking, M (2014) Modelling the impact of erosion on soil productivity: a comparative evaluation of approaches on data from southern Brazil. Exp. Agr. 34(01): 55–71.
37. Qureshi R, Singh R, Hasan M (2018) Decision support model to select crop pattern for sustainable agricultural practices using fuzzy MCDM. Environment, Development and Sustainability 20(2): 641 – 659.
38. Valera C, Valle Junior R, Varandas S et al (2016) The role of environmental land use conflicts in soil fertility: a study on the Uberaba River basin, Brazil. Sci Total Environ. 562: 463–473. doi:10.1016/j.scitotenv.2016.04.046.

Tables

Table 1

Data sets used in study

Data Required	Source
Data of Land use/land cover (LU/LC)	Maharashtra Remote Sensing Application Centre (MRSAC) Nagpur and ftp.glcf.umd.edu
Digital Elevation Model (DEM)	Shuttle Radar Topography Mission (SRTM) data (http://.srtm.csi.cgiar.org.)
Rainfall data (1998 to 2018; 21 yrs)	Department of Agriculture Maharashtra (www.mahaagri.gov.in)
Temperature data (1988-2017; 30 yrs)	WRDHP, Nashik; Department of Agronomy and CES, Wakawali, Dr. B.S.K.K.V., Dapoli; (https://swat.tamu.edu/).
Tree Diameter (girth of mango tree at breast height of 1.37 m from the ground surface)	Recorded from Mango crop field of selected villages of Ratnagiri district
Soil Data (0-15 cm and 15-30 cm soil depth)	Soil samples collected from Mango crop field of selected villages

Table 2

List of main criteria and sub-criteria in study

Main criteria	Soil, climate, topography, erosion hazard and conservation measures
Sub criteria	Rainfall, minimum temperature (T_{min}), maximum temperature (T_{max}), slope, bulk density, soil texture, organic carbon, soil loss, carbon loss related to soil loss, conservation measures and carbon sequestration

Table 3

Saaty's 1-9 scale for pairwise comparison (Saaty and Vargas, 1991)

Intensity of Importance	Definition
1	Equally importance
3	Moderate importance
5	Strong importance
7	Very strong
9	Extreme importance
2,4,6,8	Intermediate values
Reciprocals	Values for inverse comparison

Table 4

Pairwise comparison results for climate sub-criteria

Criteria	Tmin flowering stage	Tmax fruit/ harvest stage	Rainfall	Weight	Rank
Tmin flowering stage	1	3	5	63	1
Tmax fruit/harvest stage	1/3	1	3	26	2
Rainfall	1/5	1/3	1	11	3
Consistency ratio (CR)	8 % (i. e. <10 %), it shows that pairwise comparison was consistent in order to accept the weighting results or judgments.				

Table 5

Pairwise comparison results for soil sub-criteria

Criteria	Soil texture	Organic carbon	Bulk density	Weight	Rank
Soil texture	1	2	3	54	1
Organic carbon	1/2	1	2	30	2
Bulk density	1/3	1/2	1	16	3
Consistency ratio (CR)	1 % (i. e. <10 %), it shows that pairwise comparison was consistent in order to accept the weighting results or judgments.				

Table 6

Pairwise comparison results for erosion hazards sub-criteria

Criteria	Soil loss	Carbon loss	Weight	Rank
Soil loss	1	3	75	1
Carbon loss	½	1	25	2
Consistency ratio (CR)	0 % (i. e. <10 %), it shows that pairwise comparison was consistent in order to accept the weighting results or judgments.			

Table 7

Pairwise comparison results for conservation measure sub-criteria

Criteria	Conservation measures	Carbon sequestration	Weight	Rank
Conservation measures	1	2	67	1
Carbon sequestration	1/2	1	33	2
Consistency ratio (CR)	0 % (i. e. <10 %), it shows that pairwise comparison was consistent in order to accept the weighting results or judgments.			

Table 8

Pairwise comparison results for main criteria

Criteria	Soil	Slope	Erosion hazard	Climate	Cons. measure	Weight	Rank
Soil	1	3	5	7	9	50	1
Slope	1/3	1	3	5	7	26	2
Erosion hazard	1/5	1/3	1	3	5	13	3
Climate	1/7	1/5	1/3	1	3	7	4
Cons. measure	1/9	1/7	1/5	1/3	1	4	5
Consistency ratio (CR)	8 % (i. e. <10 %), it shows that pairwise comparison was consistent in order to accept the weighting results or judgments.						

Figures

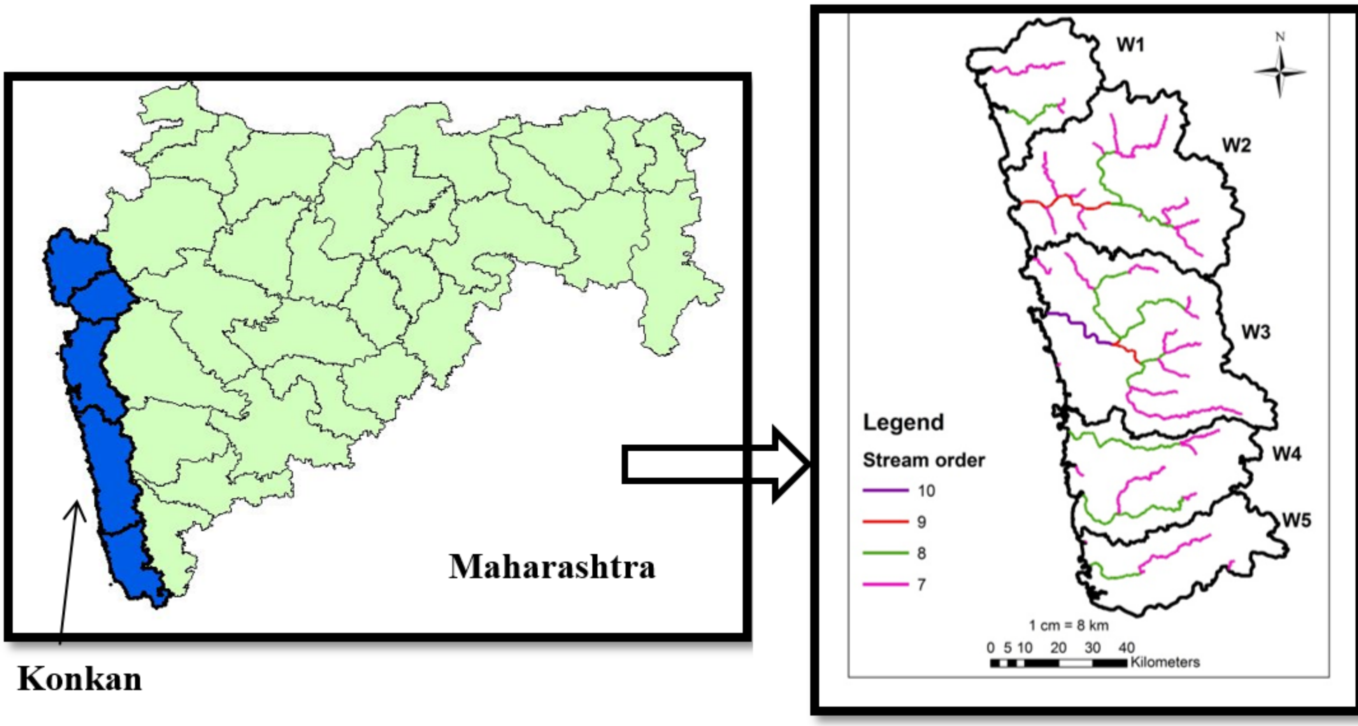

Figure 1

Location map of study area

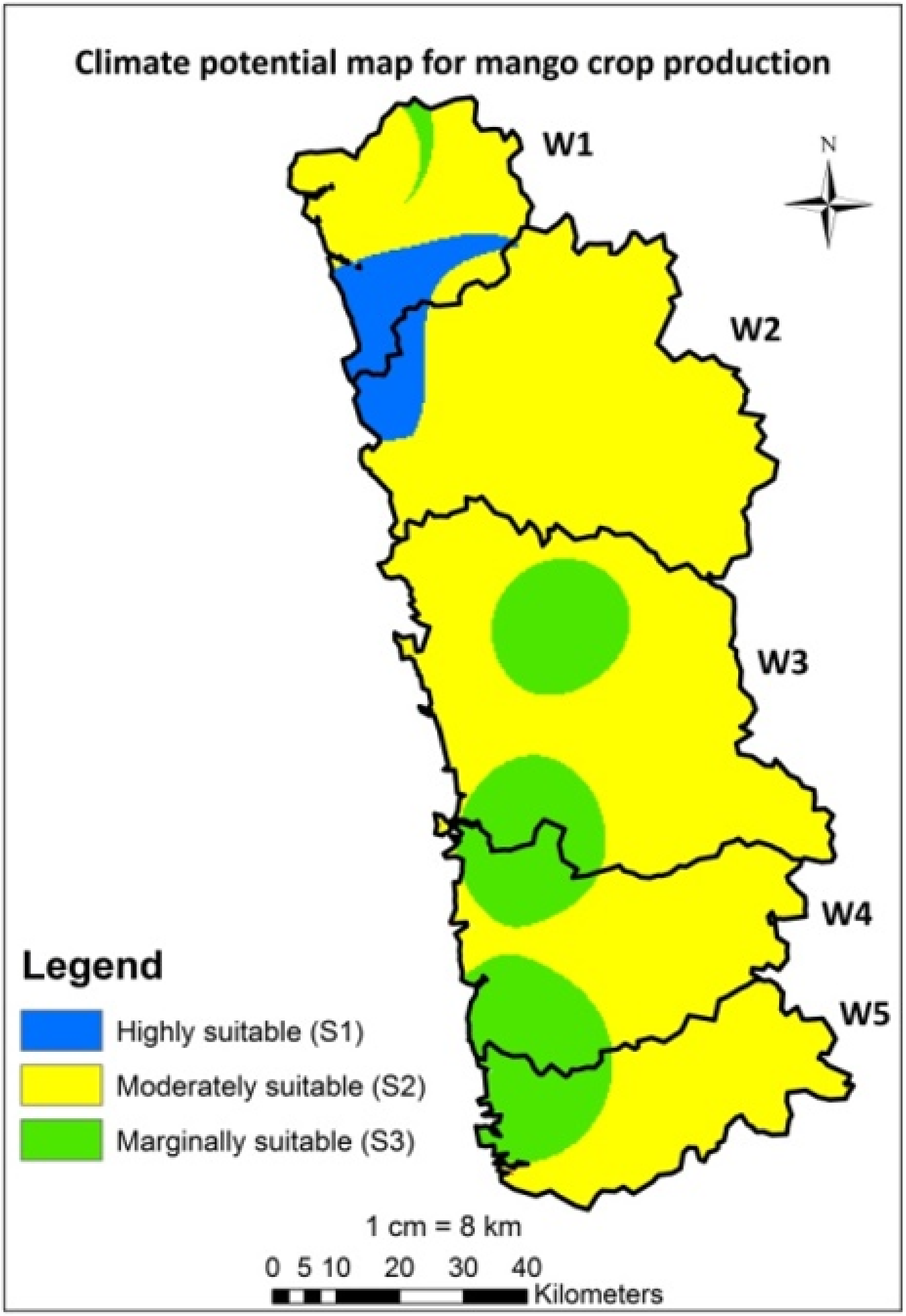

Figure 2

Climate potential for mango crop production

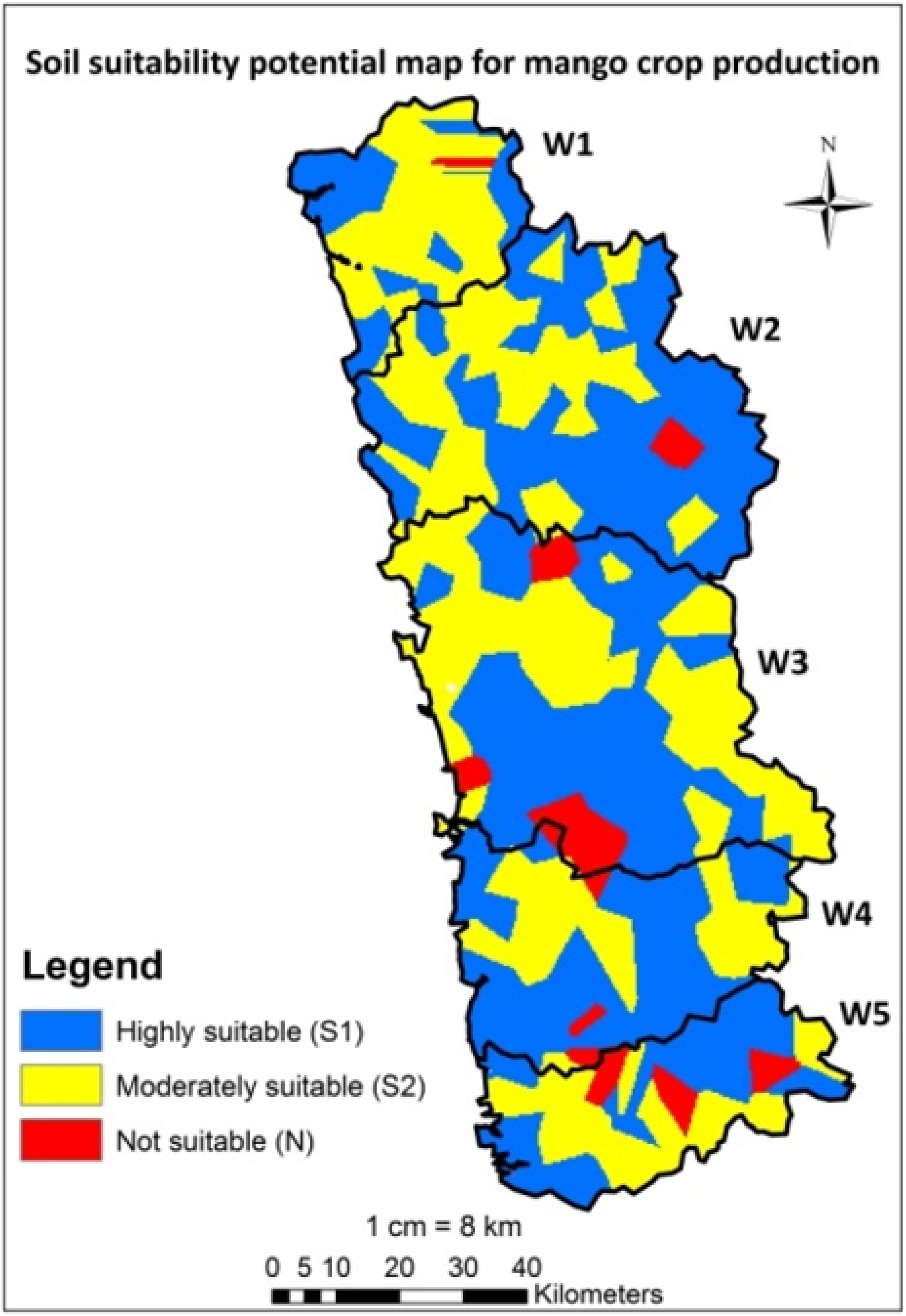

Figure 3

Soil suitability potential map for mango crop production

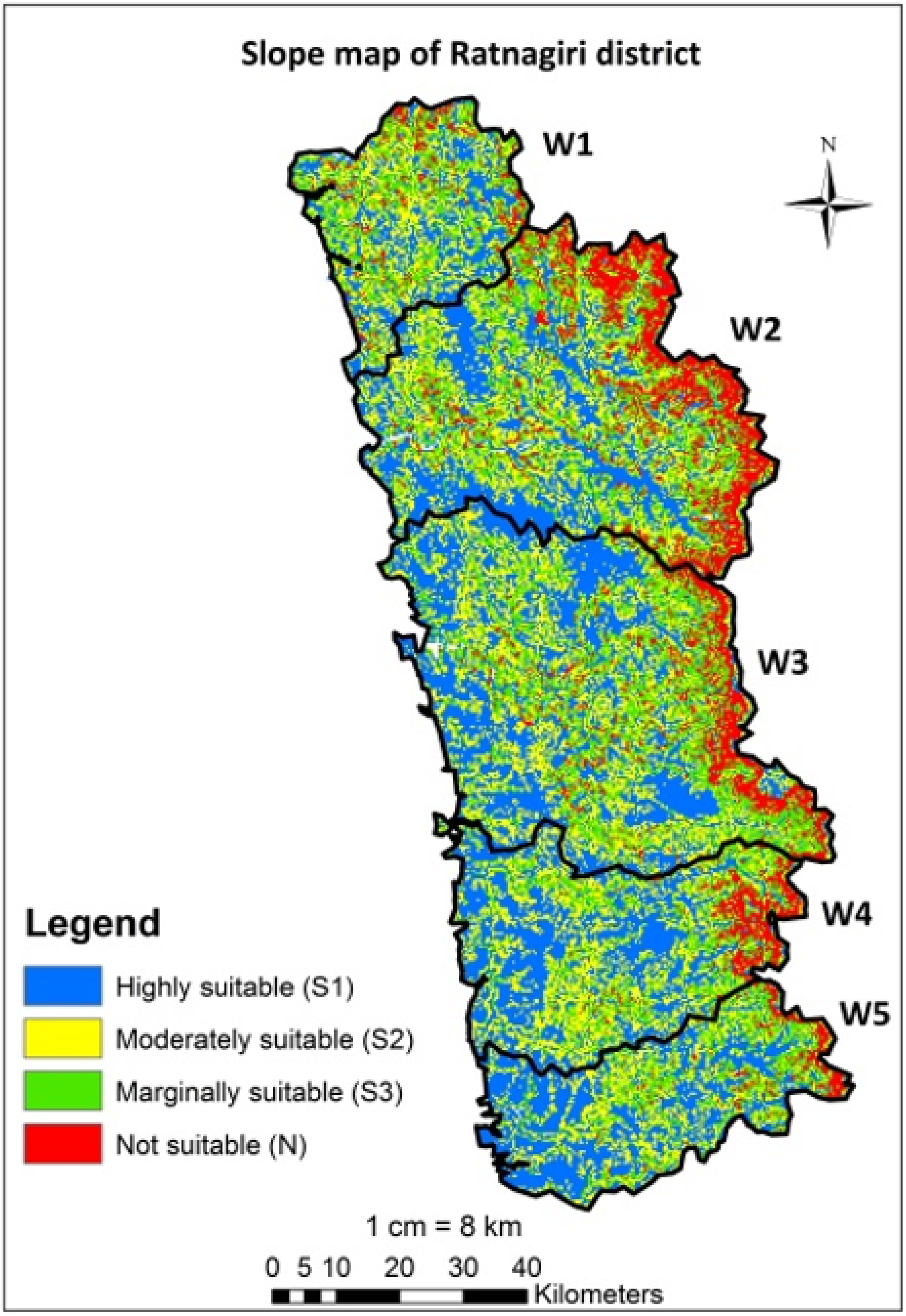

Figure 4

Slope map of Ratnagiri district

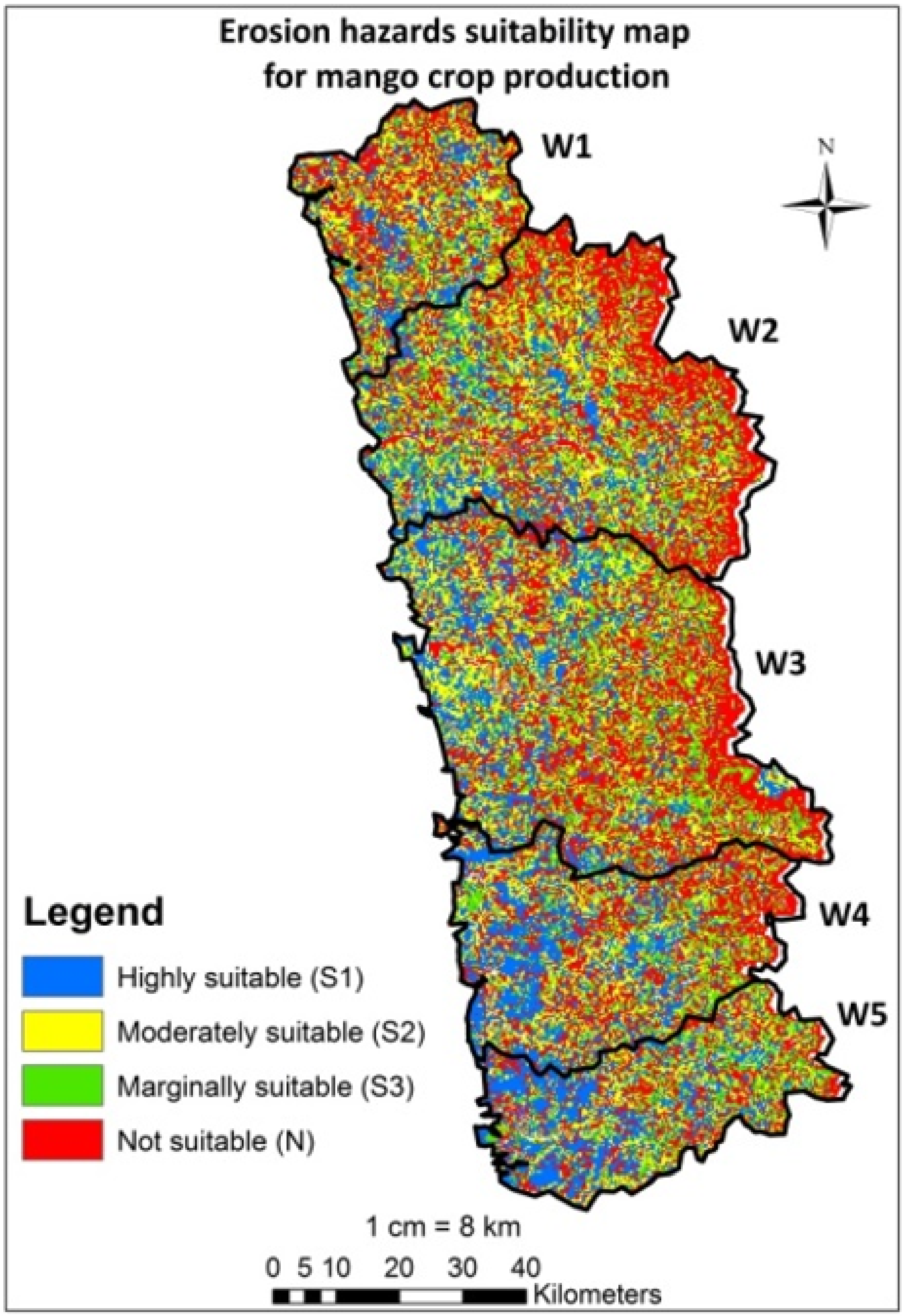

Figure 5

Erosion hazards potential for mango crop production

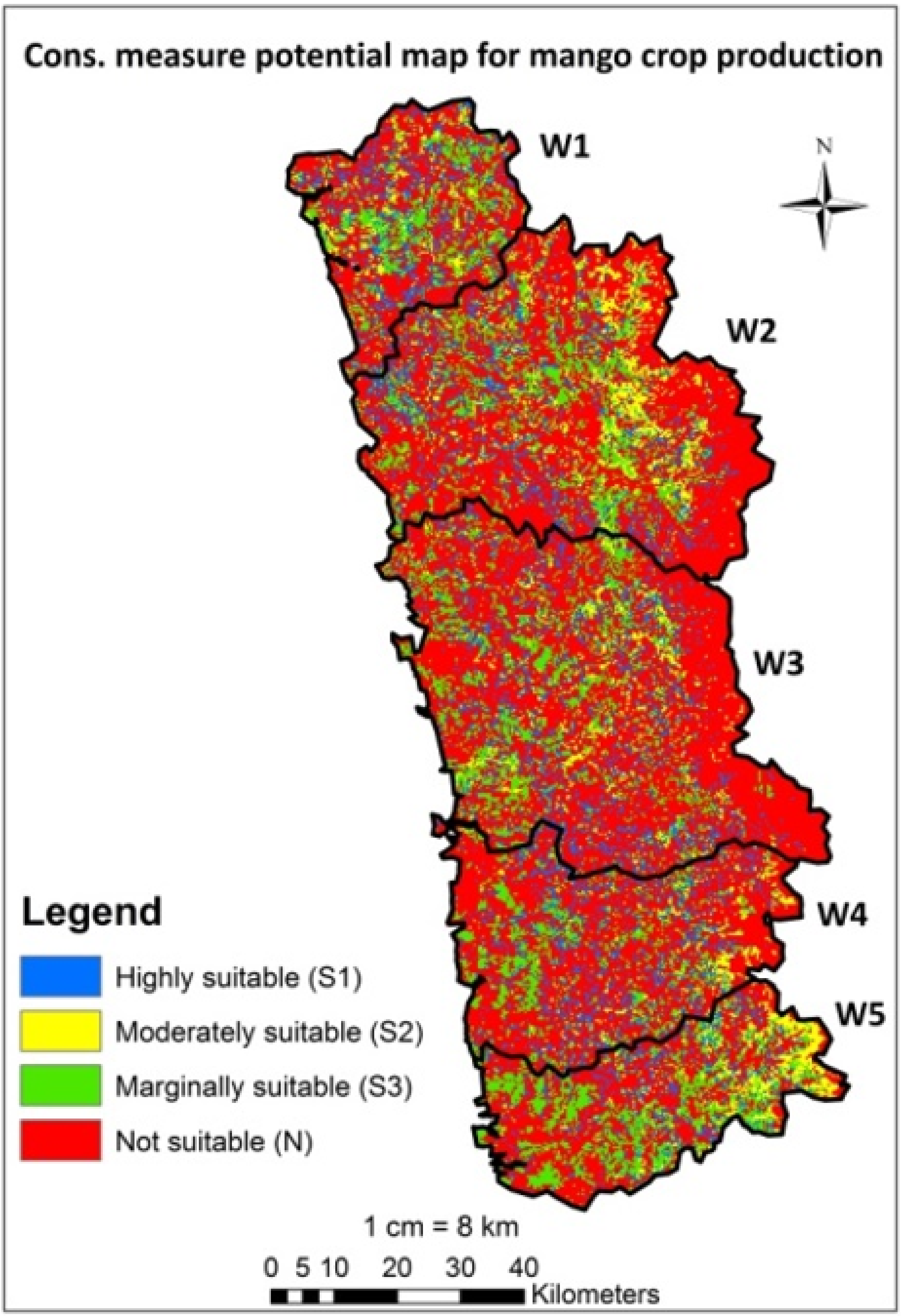

Figure 6

Conservation measures potential for mango crop production

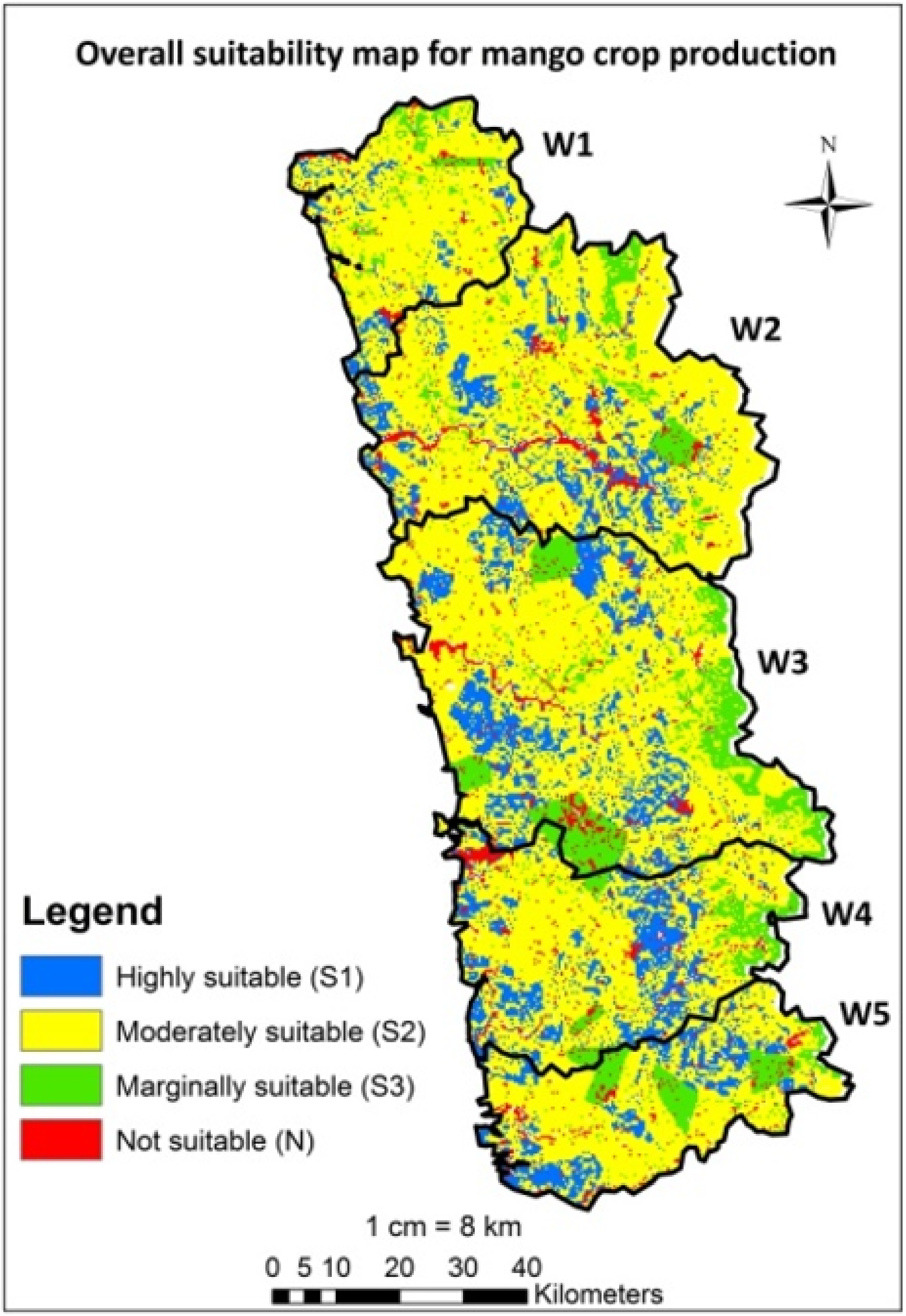

Figure 7

Overall potential for mango crop production