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A Review on Land Suitability Mapping Using Geospatial Technology

G. S. SINCHANA, A. L. CHOODARATHNAKARA AND G. A. ARPITHA
Department of Electronics and Communication Engineering, Government Engineering College,
Kushalnagar, Visvesvaraya Technological University, Belagavi - 590 018
e-Mail : sinchanagowda@ieee.org

AUTHORS CONTRIBUTION

G. S. SINCHANA : Conceptualization, manuscript preparation & collection of literature;
A. L. CHOODARATHNAKARA AND G. A. ARIPITHA : Overall direction, supervision and revising critically for intellectual content

Corresponding Author :
G. S. SINCHANA
Department of Electronics and Communication Engineering, Government Engineering College, Kushalnagar, Visvesvaraya Technological University, Belagavi

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ABSTRACT

Land Suitability Mapping (LSM) is a procedure to group specific land area in the form of its suitability based on the particular type of use. It provides geospatial information about crop cultivation in which they are well suited and also play vital role in addressing modern-day situations such as feeding more than 9 billion people, coping with climatic variations and ensuring sustainable productions. Despite this known drawbacks, an best alternative methods is necessary to delineate mapping unit for land suitability for variety of crop production. The objective of this present review is to help farmers and academic research scholars in assessing land suitability in different agricultural areas for better yield prediction using geospatial techniques. Landscape and soil factors are especially important when coupling with Geographic Information Systems (GIS) and Remote Sensing (RS) using Machine Learning (ML) techniques. This provides a guide map and superior database for making decisions in substantial growth of crops in horticulture. Review findings are based on 79 research articles with time span of eight years (2014 - 2021), collected mainly on Web of Science database. The paper identifies better geospatial techniques involved in mapping land suitability levels from various agricultural crops.

Keywords : Land suitability mapping, Remote sensing, Geospatial technology, Machine learning

LAND Suitability Mapping (LSM) is a method used to evaluate land parcel by measuring the appropriate degree of land with certain use. It pursues to distinguish which part of land is better for specific use with particular season. Since the population of earth is growing faster, which in turn resulting in shortage of human basic needs such as good shelter, better food, etc. Hence this give rise to more serious issues such as deterioration of agricultural land, scarcity of food, deforestation due to urbanization, etc., need to be addressed with better solution as early as possible. Therefore, LSM approach provides better solution to all such problems by considering land evaluation by matching the particular land abilities and compare them with land use/ land cover requirements.

Land suitability mapping can be applied to address the questions like 'where' in type of resource and land use; therefore, establishing favorable conditions for sustainable cultivation of specific crop is necessary (Mugiyo *et al.,* 2021). The agricultural activities require a major adaptation from traditional purposes to smart farming in order to face challenging tasks (Bhavikatti, 2005). Selection of location and analysis of land suitability for making decisions play a significant role. Prioritizing and selecting the better convenient zone are the most critical stages of LSA (Tercan & Dereli, 2020). Land evaluation should be performed to find suitability of the farmland for a certain use like farming / cultivation of specific crop. The major problem and challenges are selection of suitable land for crop production for particular land

and climate should be employed for assessing better yield prediction to the farmers (Dadhich *et al.*, 2017).

Further, in order to provide better yield production and outcomes to the country, specific biophysical parameters are needed to be defined for achieving success rates. To adapt predominant biophysical environmental features in any specific area, it is necessary to manage with general ecological fragility at a definite degree and then convert into more compatible livelihood and robust methods, socio-cultures, technologies and cropping patterns. Proper identification and interactions of land resources and land quality with particular use aid as a base for prioritizing land use to the productive potential (Kahsay *et al.*, 2018). Therefore, LSM approach provides better solution to all such problems by considering land evaluation by matching the particular land abilities and compare them with land use/ land cover requirements.

LSA includes several factors relevant to bio-physical elements *i.e.*, relief, slope, soil properties, atmospheric conditions, vegetation analyses, drainage, etc., as well as cultural and socio- economic aspects, morphometric characteristics in making decision process (Devi, 2014; Zolekar, 2015 and Bindumathi, 2014). Several studies in this survey were identified to combine LSA with different analysis tools comprising of irrigation requirements (Zolekar, 2018), decision support systems (Sharma *et al.,* 2018 and Habibie *et al.,* 2019) and expert systems (Purnamasari *et al.,* 2019 and Vincent *et al*, 2019).

Farmers in rural or urban areas assess their knowledge about farmland based on experiences or through observations. Therefore, such skills are inappropriate to understand the management strategies, land-use decisions and adequacy of suitable conditions. Specific applications are required for monitoring Earth surfaces to obtain particular spectral features which can be defined only through remote sensing satellite data by exploiting both cross-sensor and temporal dependencies. The development of plant growth profiles and temporal establishment of soil structure over their development stages can been enhanced through RS methods (Binte Mostafiz *et al.,* 2021).

Remote Sensing techniques offer a diagnostic system that might assist as an initial alert system, permitting agricultural communities to interfere preliminary counter potential issues earlier to which they negatively impact and spread broadly for productivity of crop. Moreover, the agricultural area is still need to implement Remote Sensing techniques due to the presence of knowledge gaps on its appropriateness, techno-economic feasibilities and sufficiency. RS allows growers to visualize, collect, evaluate soil and crop health situations at several phases of production in a cost-effective and convenient manner. Digital agriculture concepts are often applied as interchangeable to represent use of huge data sets associated with advanced environmental analytical software's and crop for supporting small holders to adopt right management activities at exact times, places and rates with goal of reaching both environmental and economic targets (Khanal *et al.,* 2020).

RS satellite data offer enormous advantages for land suitability mapping problems at several spatial and temporal scales. However, the researchers must be aware of advantages and drawbacks for more effective use of RS satellite data and select them from the accessible land suitability mapping choices accordingly. For example, at local scales, LSM with RS is very strongly affected by image acquisition time and number of imageries used. Whereas at regional and global scales, RS data are not been fully operational, asseveral methods working in one region and time are not essentially applicable to other time and locations. Therefore, at larger scales, more research work is required for identifying the best time intervals, classification methods and spectral indices under several cultural and climatic environments. From existing studies, it was observed that both RS and statistical approaches need further improvement with a significant investment of period and resources for the ground truth. An additive challenge in mapping land suitability across larger fields occurs in the fragmented landscapes with an small cultivated areas, where the spatial scales of investigations is pitted against requirement of high temporal frequencies acquisitions (Azizan *et al.*, 2021).

Previous studies have been carried out using geospatial techniques for land suitability mapping in various regions like Land Use Planning (Jamil, 2018; Sahoo *et al.,* 2021; Vasu *et al,* 2018 and Devi, 2014), Soil Informatics (Baroudy *et al.,* 2020; Binte Mostafiz *et al.,* 2021; Kim & Shim, 2018; Bhaskar *et al.,* 2015 and Singha, 2018), Site Selection (Everest, 2020; Saha *et al.,* 2020; Sarkar *et al.,* 2021 and Pramanik, 2016), Semi-Arid Regions (Kahsay *et al.,* 2018; Sahoo *et al.,* 2021; Ramamurthy *et al.,* 2020; Reza *et al.,* 2020; Taghizadeh-Mehrjardi *et al.,* 2020; Kahsay *et al.,* 2018 and Wanyama *et al.,* 2019), Coastal Regions (El Baroudy, 2016; Baroudy *et al.,* 2020; Tercan & Dereli, 2020 and Orhan, 2021), farming potential (Devi, 2014 and Wanyama *et al.,* 2019) and Watershed Regions (Roy & Saha, 2018; Masilamani, 2016; Bindumathi, 2014; Tashayo *et al.,* 2020; IliquinTrigoso *et al.,* 2020; Surya *et al.,* 2020; Bagherzadeh, 2018; Yohannes & Soromessa, 2018; Tadesse & Negese, 2020; Fekadu & Negese, 2020 and Girmay *et al.,* 2018), hilly areas (Zolekar, 2018; Zolekar & Bhagat, 2015; Zolekar, 2015; ThiTuyen *et al.,* 2019 and Pramanik, 2016).

From the identified literature, it is found that the research work carried out using optical remote sensing and GIS data have been targeted for investigating land suitability for crop growth (*i.e.* aiming to enhance crop yield), while less research has been focused on hyper spectral RS imaging for understanding and analyzing LSM for crop production. Further research work in these areas must be warranted. The main objective of the present review is to help farmers and academic research scholars in assessing land suitability in different agricultural areas for better yield prediction using geospatial techniques. This study was examined based on various article and thesis papers for drawing outline to LSM in crop production. The rest of the investigated work are considered as trails where in, Section 1 contains the Introduction about Land Suitability Mapping its challenges and requirement of using remote sensing tecnology, Section 2 comprises of studies on geospatial technology based on remote sensing satellite data and machine learning techniques, Section 3 includes studies on Land Suitability Mapping, Section 4 accomplishes the final conclusion draw from the review.

Role of Geospatial Technology used in LSM Studies

Remote Sensing Satellite Data

Remote Sensing (RS) is a valuable tool to monitor spatial-temporal differences of crop physiological and morphological status and assisting activities in agricultural field and horticulture farming (El Baroudy, 2016). RS helps to monitor land suitability in every locations around world under a different environmental conditions. RS data are less cost effective and time consuming when compared to other traditional statistical surveys that need aerial photography over a larger areas. This makes RS satellite data particularly very valuable for generating map inventories of suitable lands and monitoring it in underdeveloped countries, where funding is limited and less objective information is accesible (Azizan *et al.,* 2021).

RS applications in agricultural field include various aspects like land use and land cover management, plant phenology and economic features that will play a vital role in monitoring suitable land for crop production. At regional scales of land suitability analysis, RS satellite data gives an opportunity to involve vegetation phonological information (Purnamasari *et al.,* 2019). On the other hand, with the help of the RS satellite data with specific sensors are capable of covering huge areas with better radio metric and geometric corrections. Temporal and spatial resolutions information can be useful in th field of LSM (Jamil, 2018).

Remote Sensing and Geographic Information system (GIS) techniques are promising approaches of convenience spatial data with better productive assessment and enhanced data access to improve accuracy (El Baroudy, 2016). GIS practices include integrating satellite images with computer-based software for analysing, interpretating and mapping Earth's surface features (Jamil, 2018). GIS and RS plays a key role in handling huge amount of data comprising of climatic dataset, LULC and soil parameters obtained using satellite imagery. The digital world of RS satellite imagery also makes it comparatively easier to integrate into GIS for comparison or synthesis with other additional data sources (Azizan *et al.,* 2021).

Geo-statistical techniques were used to classify the land evaluation and generate the thematic maps to identify the suitability for land cultivation. Therefore, integrated usage of Remote Sensing satellite data and GIS has provided a way for studying dynamic land suitability for crop production (Zolekar & Bhagat, 2015 and Abdel Rahman *et al.*, 2016). For analysis of land suitability, GIS and RS techniques is much indispensable to investigate and analyze different geo-spatial parameters with higher degree of flexibility (Saha *et al.,* 2020 and Sharma *et al.,* 2018). In recent years, satellite data have proven to be valuable sources for cropping pattern and systems of assessing timely and precise knowledge, cost-effective in the spatial realm. Various research works have been highlighted for the usefulness of satellite imageries with cropping pattern and system analysis (Jamil, 2018; Singha, 2018 and Devi, 2014). Development in remote sensing satellite data and GIS methods have transformed agricultural areas and have given a substantial dimension for land suitability analysis (Sharma *et al.,* 2018).

Remote sensed data gives synoptic coverage of agricultural land in various temporal frequencies and with spectral regions sufficient to evaluate vegetation growth, harvest and maturity of different crops. The archived data that span several years will allow comparison of imageries, thus revealing changes. Moreover, RS provides essential spatial information on the specific locations of land use/ land cover requirements rather than delivering mere totals within the arbitrary of political units. Finally, RS can give information on timing, both in number of agricultural land related vegetation peaks and in length of time the agricultural land is used over the period of a year.

The detection of suitable agricultural land using RS data is a difficult process because the irrigated landscapes are subclass of crop lands which themselves have been traditionally challenging to map. As identifying suitable agricultural lands is termed to be highly dynamic because every areas might be at a different phases of development and can be subjected to miss classification with the natural land cover classes. Therefore, use of ancillary datasets on climatic conditions, soil properties and socio-economic activities can come in handy when providing explanation for these temporal data profiles (Azizan *et al.*, 2021).

A literature search was carried out to investigate if any research has been published using hyperspectral imageries for LSM purposes in recent years. This literature is spanned for 8 years (2014-2021) and review articles were collected mainly on Web of Science database research articles. It is probable that this study may have not considered few important research papers in this fields due to its non-inclusion in Web of Science database. It was observed that there was increased number of publications using multispectral RS images than the hyperspectral imaging for LSM as shown in Fig. 1. Considerably more studies has been published in recent years (*e.g.,* 79 articles published in 2014-2021).

As shown in Fig. 1, multi-spectral satellite images *i.e.,* Landsat 8 (Chozom. K, 2018; Pramanik, 2016; Binte Mostafiz, Noguchi & Ahamed, 2021; Habibie *et al.*, 2019; Saha *et al.*, 2020; Chozom and Nimasow, 2021; Seyedmohammadi *et al.*, 2019; Purnamasari *et al.*, 2019; Al-Taani *et al.*, 2021; Masilamani, P., 2016; Dedeoglu & Dengiz, 2019; ThiTuyen *et al.*, 2019; Taghizadeh-Mehrjardi *et al.*, 2020; Singha. C, 2018 and Yohannes & Soromessa, 2018), Landsat 7 (Baroudy *et al.*, 2020; El Baroudy, 2016; Devi, 2014 and Li *et al.,* 2017). Landsat 4 (Purnamasari *et al.,* 2019; Al-Taani *et al.,* 2021; Devi, 2014 and Kahsay *et al.,* 2018) and Landsat 5 (Kahsay *et al.,* 2018 and Al-Taani *et al.,* 2021 and Dedeoglu & Dengiz, 2019), Sentinel 2 (Baroudy *et al.,* 2020; Das *et al.,* 2020;

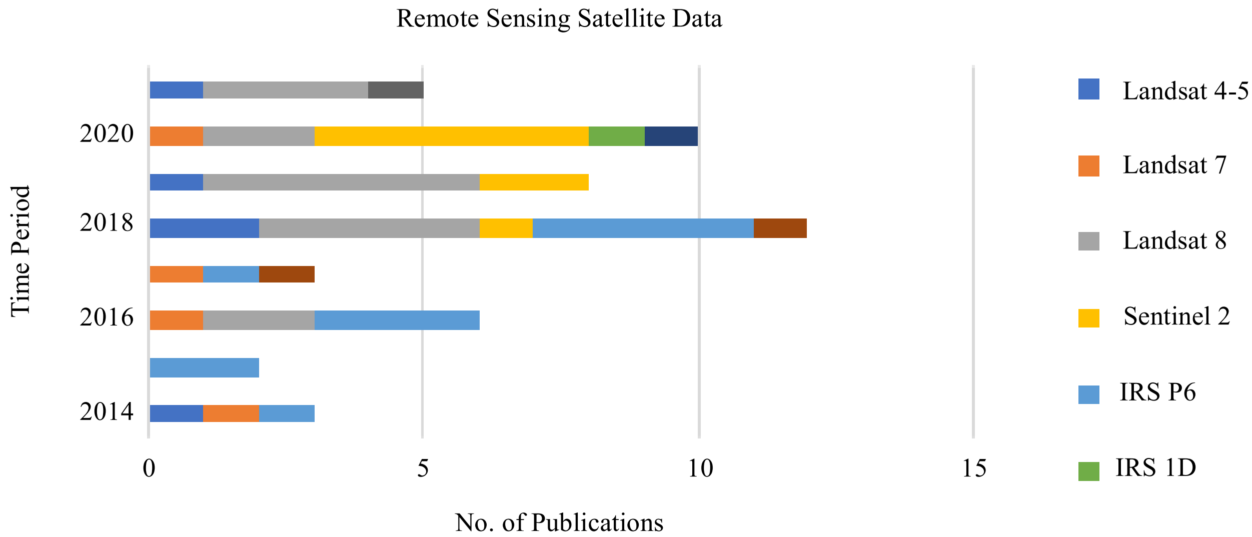

Fig. 1: Remote Sensing Satellite Data utilized for LSM Studies

Purnamasari *et al.*, 2019; Hassan *et al.*, 2020; Radocaj *et al.*, 2020; Dedeoglu & Dengiz, 2019; IliquinTrigoso *et al.*, 2020 and Purnamasari *et al.*, 2019) images has been widely assessed in studying agriculture to retrieve different crops and soil attributes like yield, soil degradation, crop chlorophyll content.

The Landsat-8 satellite data (OLI & TIRS) was used for analyzing land suitability in West Kameng District with different spatial resolution and temporal resolution. Out of 277,300 Ha of total area, 205.6 km^2 area of results achieved 4.22 per cent accuracy as 'highly suitable', 39.41 per cent of area (1938.1 km^2) as 'suitable', 23.31 per cent (1,1461.1 km^2) as 'moderately suitable', 25.17 per cent (1238.1 km^2) as 'marginally suitable', 7.97 per cent (392.1 km^2) as 'least suitable' for the cultivating the apple tree (Chozom. K, 2018). The author (Radocaj *et al.*, 2021) suggested that as a further study, high resolution satellite (Sentinel 2) data scaling should be implemented and multiple crop types are needed to be directed at micro-locations. The assessed literature includes few researches in multi-temporal RS satellite data for monitoring spatio-temporal changes in suitability analysis of land (Habibie *et al.*, 2019 and Binte Mostafiz *et al.*, 2021).

A MCDM method using IRS P6 LISS IV data by GIS environments are used to detect land suitable areas in agricultural fields. Literature review, correlation method and expert's opinion were applied to adopt influencing factors, judgment formation and assigning ranks to sub criteria using pairwise comparison matrix. The ERDAS imagine 2013 software were applied to geometrically correct the 14 ground control points from topo-graphic maps, which are geocoded using TM images. The RSME value for 0.5 pixels is unacceptable, whereas values less than 0.4 pixels is acceptable. The satellite imagery was procured with cloud free data and atmospheric correction to achieve error free data. Geographical information about climatic conditions, restrictions of pest and diseases, with the exemption of dry periods and relative humidity data were achieved using WorldClim 2.1 during 1970-2000 period with appropriately 1km resolution.

As depicted in Table 1, it was noted that satellite-based multi-spectral sensors like Sentinel - 2 and Landsat data has been commonly used for mapping land suitability in agricultural applications. There are other few remote sensing satellite senors considered for assessing land suitability in agricultural field. For instance, Indian Remote Sensing Satellite P6 (IRS P6) is a multi-spectral sensor equipped on Indian Space Research Organization (ISRO). Its spatial resolution is 23.5m (LISS III) (Bindumathi, 2014; Rath *et al.*,

TABLE 1

Previous studies carried on RS images with its data characteristics for LSM

Data Characteristics Based Land Suitability Mapping										
Remote Sensing Satellite Data	Operators	Sensors	Swath (km)	Bands	No. of Spectral Bands	Spectral Range (µm)	Spatial Resolution (m)	Temporal Resolution (Days)	Radiometric Resolution	No. of Publications
Sentinel - 2	ESA	MSI	290	MS	12	0.443 -2.19	10-60	5	12 bits	8
Landsat 4 - 5	NASA NOAA	MSS TM	185	MS MS Thermal	4 7	0.5-1.1 0.45-12.5	60 30 120	16	8 bits	0 5
Landsat 7	USGS	ETM+	183	MS Thermal PAN	8	0.45-12.5	30 6 15	16	8 bits	4
Landsat 8	USGS TIRS	OLI	185	MS PAN Thermal	8 2	0.43-2.29 10.6-12.51	30 15 100	16	12 bits	1 6
IRS P6	ISRO	LISS III LISS IV	140 3070	MS Mono- chromatic	5 4	0.52-1.70	23.5 ≤ 5.8	12-13 5	10 bits	6 5
IRS 1C IRS 1D	ISRO	LISS III	142	MS PAN	4	0.52-1.7	23 50	24	7 bits	1 1
Cartosat-1	ISRO	PAN – F PAN - A	29.42 26.24	PAN	1	0.5-0.85	2.5 2.22	5	10 bits	2

Table 1 contd....

Data Characteristics Based Land Suitability Mapping

Remote Sensing Satellite Data	Operators	Sensors	Swath (km)	Bands	No. of Spectral Bands	Spectral Range (µm)	Spatial Resolution (m)	Temporal Resolution (Days)	Radiometric Resolution	No. of Publications
PROBA	ESA	V	2250	MS SWIR	4	0.438-0.194 1.564 –1.634	100 200	1	—	1

List of Abbreviations: ESA – European Space Agency, MS - Multispectral, MSS – Multispectral Scanner, PAN - Panchromatic, MSI – Multispectral Instrument, TM – Thematic Mapper, OLI – Operational Land Imager, TIRS – Thermal IR Sensor, ETM+ - Enhanced Thematic Mapper, LISS – Linear Imaging Self Scanning Sensor, PAN-F: Panchromatic FORE, PAN-A: Panchromatic AFT, NASA – National Aeronautics and Space Administration, NOAA – National Oceanic and Atmospheric Administration, ISRO – Indian Space Research Organization, USGS – United States Geological Survey, IRSP6 – Indian Remote Sensing Satellite P6, PROBA – V : Project for On Board Autonomy Vegetation.

2018; Abdel Rahman *et al.*, 2016 and Dadhich *et al.*, 2017; Jamil, 2018; Masilamani, P., 2016; Rath *et al.,* 2018) and ≤5.8m (LISS IV) (AbdelRahman *et al.*, 2016; Zolekar and Bhagat, 2015; Zolekar, 2018; Zolekar, 2015; Vasu *et al,* 2018) in the range of 0.52-1.70 µm. Indian Remote Sensing Satellite (IRS 1C) (Ramamurthy *et al.,* 2020) and (IRS 1D) (Surya *et al.*, 2020) is an multi-spectral mission with LISS III sensor launched in 1995. It acquires spectral signatures in the range of 0.52-1.70 µm with a spatial resolution of 23m (MS band) and 50m for the panchromatic band. Cartosat-1 is a panchromatic imaging system collects data in the range 0.5-0.85 µm with spatial resolution of 2.5m and 2.22 m for the panchromatic band. To compute cropland suitability at the global levels, a data driven medium resolution satellite mission, Project for on Board Autonomy Vegetation (PROBA-V) was launched on May 2013 (Radocaj *et al.*, 2021). This sensor will extract multi-spectral images with spatial resolution of 100m in the spectral range of 0.438-0.194 µm and 1.564-1.634 µm of shortwave infrared (SWIR) with a spatial resolution of 200m (Radocaj *et al.,* 2021).

The aspect and slope of terrain were collected by Digital Elevation Model (30m spatial resolution) from NASA's SRTM using QGIS3.10 tools. The analysis of land suitability for coffee production showed that 2628.00 km^2 (18.6%), 966.92 km^2 (8%) and 1208.18 km^2 (7.6%) presented sub-optimal, unsuitable and optimal territory for development of pests and diseases. It is termed as optimal territory for coffee cultivation in Amazon region (Salas Lopez *et al.*, 2020). To support and help the small-scale farmers to improve crop productivity in agriculture, research was extended for in Amazonas region for yield of potato farming (Iliquin Trigoso *et al.,* 2020). Monitoring of the agricultural crops, plant diseases, soil moisture, crop health and yield estimation can be explored using various satellite imageries (Sharma *et al.*, 2021; Sharma *et al.*, 2018).

The present review on Remote Sensing satellite data in agricultural crop production was focused on creating awareness about new satellite data and technologies in the LSM. The information available from Remote Sensing data is more valuable to make decision for agriculture depending on particular things of its platforms and sensors like orientation and positioning of UAS's, sensor characteristics and positioning of satellite orbits. Whereas high resolution images are useful to applications like crop growth phase identification, crop counting, recurrent access to images at detailed growth phases and weed detection is valuable to capture within season changeability in nutrient stresses and crop water. Correspondingly, capturing spectral signature images in various spectral (narrow) bands in EMR's (Hyper spectral images) can aid to enhance the identification, classification and characterization of soil and crop properties or else it would be problematic to accomplish by evaluating only a small broad (spectral) band.

With help of such new approaches and methods, it is able to meet essential food demands by reducing or maintaining environmental foot steps of horticulture. The existing literature survey is planned to support agricultural scholars and experts to realize the limits and strengths using hyper spectral imagery in the agriculture and also to encourage the acceptance of this valuable technologies. Use of hyperspectral sensor is relatively exclusive and size of data is also enormous and hence, it requires wide calculations. Hyper spectral images can be processed by state-of-art using image segmentation algorithms to develop solely objects that sometimes corresponds to physically significant features *e.g.,* a crop land unit cultivating wheat crop. Hence, a literature search was carried to investigate, if any research using hyperspectral satellite data for agricultural crop production had been done in recent years. Therefore, it is recommended to use hyper spectral imagery research on the agricultural crop production for mapping land suitability. In overall summary, from the literature identified, RS techniques can be applied to assist area specific decision managing at several phases of production of crop helping to improve and address the profitability, sustainability and environmental quality of crop production.

Machine Learning Techniques

In recent days, number of applications in ML approaches for agriculture are needed to access big amount of data from numerous resources to find and analyze the hidden knowledge. The incorporation of computer science field with agricultural practices can help in predicting agricultural crops. It is essential to build an objective methodology for pre-harvesting crop predictions. To build a well suite model can have specific benefits over traditional prediction approaches. Such advanced research fields are expected to develop in further upcoming days (Mishra *et al.,* 2016). Recent evolving technologies like Internet of things (IOT), geo-spatial techniques, Artificial Intelligence (AI), Big Data analysis can be explored for making decisions that are needed to increase the crop production. Similarly, obtainability of huge set of satellite data have driven scholars to discover advanced processing methods and data storage *i.e.,* machine learning and cloud computing, etc. (Sishodia, Ray & Singh, 2020).

The data extracted through many sensors are then handled through MLP to ensure better performance measures. Therefore, with a proper system and precise instructions it could enhance the results still more. The results obtained have been epitomized for over ten classes individually using MLP and NN by varying $N_!$ values of 30, 50, 80. The experimental results obtained for averaged ten multiclass classifications using MLP and NN was done by varying N_h values of 30, 50, 80 (Vincent *et al,* 2019). In order to reduce dimensionality issues on hyperspectral data, utilization of machine learning techniques, several vegetative indices and statistics like random forest (RF) and deep convolutional neural network (DCNN) can be helpful to extract useful information required on crop growth conditions (Sishodia, Ray & Singh, 2020).

According to Mokarram *et al.,* 2015, the major factors affected LS are slope, micro relief, ESP, texture, EC, pH, gypsum, water table depth, slope primary, depth of chroma, CaCO3 was evaluated randomly for five points. The outcomes of RF, Bagging method, Ada

Boost, single tree algorithm provided better accuracy than other technique. The proposed methods were not able to forecast land suitability class precisely for all full points. Hence, land suitability determination of Rot Boost algorithm can be applied in place of FAO and different approaches. The RotBoost model has shown better accuracy and faster than the remaining methods used for classifying land suitability. A study was conducted on LSM in India to execute reliability test at national levels using ML based sensitive analysis and hybrid Fuzzy AHP techniques. From this experimentation work, they found that with the use of low spatial resolution imageries can be very critical to assess land planning at micro-levels (Talukdar *et al.*, 2022).

The author Surya *et al.*, 2020 recommended that higher productivity of crop suitability can be achieved at micro level, by applying decision tree method to obtain optimal utilizations with available natural resources. A study on land suitability with multicriteria analysis and geographical extent for production of maize was processed using Landsat 8 to generate soil-adjusted vegetation index (SAVI), land surface temperature (LST) and normalized difference vegetation index (NDVI) using Maximum Likelihood Classifier (MLC) method in ArcGIS software (Habibie *et al.*, 2021).

The research (Vincent *et al,* 2019) was proposed on an expert system to assess agriculture LS by integrating sensors with AI systems like Multi-Layer Perceptron (MLP) and Neural networks. The work carried out for the proposed model had obtained most desirable accuracy of 99 per cent. The outcomes found to be effective with use of multiple classification system rather than the other models using MLP with four hidden layers. The author used Support Vector Machine (SVM), Random Forest (RF) algorithms to assess land suitability for rainfed barley and wheat crop production in Kurdistan province, western Iran. The overall accuracy and kappa index predicted using Random Forest method for LS class (0.79 and 0.77) was high when compared to values from Support Vector Machine method (0.63 and 0.57) for rainfed wheat, respectively. The accuracy and kappa index predicted using RF method for LS class (0.69) and (0.73) was higher than the SVM (0.58 and 0.66) for rainfed barley, respectively. The proposed technique can be able to provide information and guide to provincial land use policy and planning development for growth in Iran, but this method can also be used in other countries for various other crops (Seyed mohammadi *et al.,* 2019; Taghizadeh-Mehrjardi *et al.*, 2020).

To assess LS using GIS, a work was explored to find the capability of feed-forward network using Back Propagation Neural Network (BPNN) and 83.43 per cent of acceptable performance rate was achieved with use of ANN for production of paddy. Further, in upcoming days the ANN training applied in this method can be applied by integrating ANN and fuzzy logic. The gaps identified through this article was that ANN approaches can be made more flexible and better with use of ranges than using actual values (Farnood Ahmadi & Farsad Layegh, 2014). The GIS, AHP and Machine learning (SVM, Bagging methods and ANN) models were employed to regulate soil fertility and land suitability in West Bengal region for semi-humid climatic zone, achieving 18.01 per cent of area as excellent suitability to cultivate rice crops (Sarkar *et al.*, 2021).

A fuzzy method and parametric based Neural Network approaches were explored by comparing observed value and land index value for production of irrigated soyabean (Bagherzadeh *et al.,* 2016), whereas for production of irrigated wheat, they have used TOPSIS and parametric approaches (Bagherzadeh and Gholizadeh, 2016). Similarly, for production of irrigated alfalfa in Iran regions, TOPSIS and parametric based NN method was applied (Bagherzadeh and Gholizadeh, 2016). Further more, studies were conducted using parametric approach of MCE by applying GIS techniques to evaluate LS for production of irrigated wheat and barley in Iran region, resulting for about 65.8 per cent to 62.0 per cent as marginally suitable, 10.4 to 1.2 per cent as not suitable and 23.8 to 36.8 per cent as moderately suitable (Bagherzadeh and Mansouri Daneshvar, 2014).

Similar, experimentation work was conducted to analyze LS in the semi-arid region of Iran with use of AHP and parametric approaches for black locust and Norway maple tree plantations (Bagherzadeh, 2018). The work carried out by author (Moller *et al.,* 2021) aimed to deliberate and elucidate the connection to forty-one varieties of special crops by linking LSM with Machine Learning model (Maxent) on basis of mechanistic crop algorithm requirement (ECOCROP) in Denmark region and observed that ML can classify the areas, wherever the agriculturist normally grows particular crops.

In this system, GIS is integrated with Linear combination method and have chosen ten criterions based on topographical, physical and chemical affecting wheat production in basin and divided into forty-seven land units based on thematic soil maps. The WSI score values was compared with NDVI and yield values considering five years (2013 to 2017) data for model testing. The land classification for wheat crop has been determined with accuracy of r^2=0.83 per cent (yield) and r^2 = 0.78 per cent (NDVI). It was found that WSI model was appropriate technique specifically in semi-arid climatic conditions (Dedeoglu & Dengiz, 2019).

It was observed that expert's opinion is an important factor that vary accordingly. Under such situations, WCPA offers a better viable alternate (Mistri and Sengupta, 2019). The yield prediction model developed for highly suitable areas are using vegetation indices with help of Sentinel 2 data of 10m resolution. The research study was performed to formulate LSE maps for yield of wheat crop using GIS model and compare it with storie and square root technique for the study area. Total 90 points are observed to check accuracy of land mapping units. From several physiographic units, 27 soil profiles were taken. The proposed model obtained after comparison of both methods showed that 7.27 per cent of soil is highly suitable class (S1), 21.58 per cent unsuitable class (N), 64.17 percent is moderately suitable (S2) and 6.97 per cent is marginally suitable class (S3) are quite differed than the outcomes of square root approach. Whereas, for storie method showed that 44.71 per cent is marginally suitable, 26.07 per cent is highly suitable for soil, 21.58 per cent is unsuitable class and 7.63 per cent is moderately suitable (El Baroudy, 2016).

The research work demonstrated by author (Kylyc *et al.,* 2022), recommended that integration of Fuzzy AHP and GIS methods is an applicable and effective approaches to provide better decisions in the agricultural land use management purposes for wheat cultivation. The herein model (where Storie, Root, Micro LES and ALES) was proposed using RS satellite data to compute NDVI time series for cultivation of rice crop and extract geomorphologic units (Baroudy *et al.,* 2020). Performance of model was estimated and compared with hybrid method (AHP-Matter element) having R^2 = 0.947. The attained results to select best suitable area for barley yield in Iran were more precise than square root and storie methods (Seyed mohammadi, 2019). The storie and square root method was undertaken to study LSE for agricultural crop production covering an 43,700 ha, due to improper land management activities in Fakkeh region (Albaji and Alboshokeh, 2017).

AHP method is a powerful tool that deals with inconsistent findings and offers inconsistency for about 19.76 per cent of area that are located in north eastern regions of country. The combination of AHP and GIS in LSA, provide high correlation of R^2 = 0.63-0.85 achieved between suitability indices and maize yield which reflect effectiveness and classification accuracy (Chivasa *et al.,* 2019). Based on expert opinions, AHP method achieved 64.9 per cent (125,216ha) as highly suitable, 30.4 per cent (58,828 ha) as moderately suitable, 4.5 per cent (8603 ha) as marginally suitable. NDVI and SAVI value indicated for yield estimation have attained R^2 = 77.81 per cent and 72.8 per cent as highly suitable areas (Habibie *et al.,* 2019). The NAVI, LAI, Fapar, IRECI and SAVI were applied for model prediction of cassava production. As per vegetation indices, NDVI occurred higher accuracy of R^2 = 0.62 in predicting model yield when compared to IRECI and SAVI. Correspondingly, LAI had obtained higher accuracy prediction of

$R^2 = 0.70$ rather than biophysical variables (fAPAR) (Purnamasari *et al.,* 2019).

Using Landsat 8 satellite images, SARVI, MASAVI, OSAVI, ARVI and SAVI were acquired to determine land conditions and soil affiliated indices. Estimated yield (R^2) coefficient for ARVI, SAVI, MSAVI, SARVI and OSAVI is 68.9, 77.3, 74.5, 71.1 and 81.2 per cent had predicted good ability. Moreover, combined model from five indices provided maximum accuracy of R^2 as 0.839. Hence such model can be applied to produce yield prediction mapping for alternate years of 2017-2020 (Binte Mostafiz *et al.,* 2021).

Using AHP based multi-criteria and spatial analysis, a suitability model for cultivation of saffron was developed to offer a methodological method to study land use suitability. In this study, they have considered five indicators *i.e.*, NDVI, slope, Temperature-Vegetation Dryness Index (TVDI), yield and light-temperature potential productivity. Analysis of land suitability for saffron cultivation showed 5.48 per cent of area (1743.25 ha) as highly suitable, 10.04 per cent (3197.30 ha) as moderately suitable, 65.96 per cent (3197.30 ha) were located as unsuitable zone (Maleki *et al.,* 2017). A Modified Normalized Difference Water Index (MNDWI), Modified Soil Adjusted Index (MSAI) and Consistency Index (CI) was computed, taking into contemplation of different factors applied in land suitability for anabranching site of sooin river, India. Overall, 16 parameters are considered for land suitability mapping. The LULC map was generated using Landsat-8 imageries by adopting supervised technique (Maximum likelihood classifier) and the 86 per cent of accuracy was achieved with help of the Kappa statistics (Saha *et al.,* 2020).

The article aimed to evaluate LS to notice suitable agricultural land in Sri Lanka for tea production. The validated model provided 92.46 per cent of accuracy for tea growing classes as very suitable and highly suitable modelled classes showing total robustness of a model and applied weightings. The research work carried out can be an effective method to improve better management, land policy makers and land use planning efficiency for growing tea production (Layomi Jayasinghe *et al.,* 2019; Das *et al.,* 2020). A study was attempted to help small scale farmers in LS with major four decision methods (trapezoidal and triangular FAHP, parametric and AHP) by three main covariate groups (Topography, Climate and Soil) in Thailand region and outcoming to more than 90 per cent accuracy of area as suitable to cultivate eucalyptus plantation (Rodcha *et al.,* 2020).

From Table 2, it was noted that RF, PCA, KNN, Linear Regression analysis and SVM are commonly used models in the digital soil map and little attempt has been occurred to map land classes in past few decades because of their comparatively better accuracy, ease of use and robustness. From the existing literature, only few researches have been presented on ML application and deliberated how digital technology can aid benefit for both agricultural practices and industries (Mishra *et al.*, 2016; Sharma *et al.*, 2021; Mugiyo *et al.*, 2021) as shown in Fig. 2.

This review paper has attempted on the importance of ML approaches in field of agricultural crop cultivation. Timely and accurate prediction of crop production are essential for significant policy decision making such as pricing marketing distribution, export-import, etc. are issued from directorate of statistics and economics. The issues to intricate skills from the raw data can lead to growth

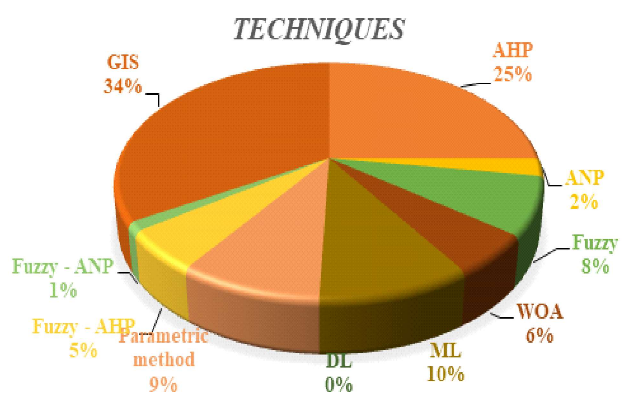

Fig. 2: Specification of various techniques published for land suitability mapping in the year 2014- 2021. (Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Weighted Overlay Analysis (WOA), Machine Learning (ML), Deep Learning (DL)).

TABLE 2

Previous studies based on methods in several crops for LSM

Previous Studies	Study Area	Crops	Methods	Indices	Accuracy Assessment	Purpose
Purnamasari et al., 2019	Indonesia	Cassava	AHP & ANP	NDVI	S1 - 41.60%, S2 - 30.87%, S3 - 9.83% & N1 - 17.69%	To perform LS levels by integrating RS, GIS & AHP for cassava production
Habibie *et al.,* 2019	Indonesia	Maize	AHP, RS, GIS - MCDA	NDVI & SAVI	S1 - 70.8%, S2 - 26.3% & S3 - 2.8%	To regulate the land that are appropriate for maize production by RS and spatial data
Binte, Mostafiz *et al.,* 2021	Bangladesh	Agriculture	WLC & Fuzzy MCA	SAVI, ARVI, SARVI, MSAVI & OSAVI	S1 - 43%, S2 - 41% & S3 - 10%	To identify the suitable agricultural land using RS data integrated with WLC and Fuzzy MCA
Baroudy *et al.,* 2020	Nile Delta	Rice	RS & GIS	NDVI	S1 - 44.44%, S2 - 44% & N1 - 11.56%	To determine a new approach for LE and map the soil suitability in rice crop
Dedeoglu & Dengiz, 2019	Turkey	Wheat	AHP & GIS	NDVI	S1 - 17.98%, S2 - 14.07%, S3 - 22.76% & N1 - 45.19%	To generate WSI using hybrid method of AHP & GIS for wheat crop
Taghizadeh - Mehrjardi *et al.,* 2020	Iran	Rain-fed wheat & barley	RF & SVM	NDVI SAVI, EVI, BI	N2 - 30.00% - 24.50%, N3 53.50% - 59.00% & S3 16.50% - 18.50%	To develop LS for two main crops in Kurdistan province, Iran
Purnamasari *et al.*, 2019	Indonesia	Cassava	GIS, Fuzzy - MCDM	NDVI, SAVI, IRECI, LAI & fAPAR	S1 - 42.17%, S2 - 43.10%, S3 - 6.25% & N1 - 8.47%	To assess a LS model for finding the suitable areas for Production of cassava
Singha, 2018	West Bengal, India	Rice, Potato, Oilseeds and Jute	AHP, Fuzzy, RS & GIS	NDVI,	S1 - 29.2%, S2 - 15.1%, S3 - 51.2% & N1 - 4.5%	To obtain LSA for selecting best crop rotation and cultivation of crops
Zolekar & Bhagat, 2015	Maharashtra, India	Varai, Nagali & Khurasani	AHP, MCDA GIS, WOA	NDWI & SMI	S1 - 17%, S2 - 29%, S3 - 16% & N1 - 38%	To evaluate the LS for agricultural fields in hilly areas

Table 2 contd.....

Previous Studies	Study Area	Crops	Methods	Indices	Accuracy Assessment	Purpose
Zolekar, 2015	Maharashtra, India	Rice & Bajara	AHP & Fuzzy,	NDWI, LAL & NDVI	S1-5%, S2-23%, S3-14% & N1-58%	To identify LSA and strategies for sustainable development
Jamil, 2018	Bijnor District, U. P.	Multiple Crops	FAHP & WOA	MCI & ADI CLUI	N3 - 10% & N2 - 4%	To use multi-temporal satellite images for studying change of cropping pattern and systems
Das *et al*., 2020	Bangala desh	Tea	GIS, AHP & RS	NDVI & LAI	S1 - 23%, S2 - 58%, S3 - 18% & N1 - 1%	To find the suitable lands for Tea production using GIS, RS and AHP
Saha *et al.,* 2020	West Bengal & Bihar, India	Agriculture	AHP & GIS	MSAVI, MNDWI	S - 4.11%, S1 - 28.65% & S2 - 49.67%	To determine suitable areas for agricultural practices
Pramanik, 2016	Darjeeling District	Tea	AHP & GIS	NDWI	S1 - 53.1%, S2 - 29.82%, S3 - 24.27% & N1 - 40.60%	To evaluate suitable areas for tea production using GIS and AHP method
Radocaj *et al*., 2020	Osijek-Baranja	Soyabean	AHP & GIS	NDVI	S2 - 14.5%, S3 - 64.3%	To assess optimal soyabean LS and map using MCA
Radocaj *et al.,* 2021	Croatia	Soyabean	ML - RF & SVM	LAI, fAPAR	RF & SVM: Subset A - 76.6% to 68.1%, Subset B - 80.6% to 79.5%	To propose a novel cropland suitability assessment and accuracy assessment approach based on machine learning
Maleki *et al*., 2017	Iran	Saffron	MCE & GIS	NDVI & TDVI	S1 - 5.48%, S2 - 10.04% & N1 65.96%	To forecast limitations and potentials of land for production of plant
Devi, 2014	Tamil Nadu	Multiple Crops	RS & GIS	NDVI	-	Conservation of important plant species in land-use planning, land-use suitability evaluations

List of Abbreviations: NDVI – Normalize-d Difference Vegetation Index, NDWI – Normalized Difference Water Index, WSI – Wheat Suitability Index, MNDWI – Normalized Difference Water Index, SAVI – Soil Adjusted Vegetative Index, ARVI- Atmospherically Resistant Vegetation Index, SARVI - Soil Adjusted and Atmospherically Resistant Vegetation Index, MSAVI – Modified Soil Adjusted Vegetative Index, OSAVI – Optimized Soil Adjusted Vegetative Index, EVI – Enhanced Vegetation Index, BI – Brightness Index, IRECI – Inverted Red Edge Chlorophyll Index, LAI – Leaf Area Index, fAPAR – Fraction of Photosynthetically Active Radiation, Modified SMAI of new method and approaches like ML technique in order to unite the information of data with crop production. Some of the methods like deep learning, transfer learning, convolutional neural network, deep neural networks, artificial neural networks, Time series analysis, k-means clustering and Bayesian belief network can be applied to map land suitability for various crop production.

Land Suitability Mapping

Land suitability mapping (LSM) is an approach to avoid some environmental conflicts using segregation process by competing on land uses. Land suitability study is a very significant approach in making decisions for agricultural cropping systems and patterns, activities and planning management, etc. LSM can be either quantitative or qualitative method. Qualitative method basically applied to evaluate land suitability on a wider scale and provide outcomes in qualitative terms. The quantitative method uses parametric technique to give details about the land parameters by performing several statistical analyses. LSM process is quantitative type method involving more simulation modelling models (El Baroudy, 2016).

The study conducted in Hemavathi watershed areas was on basis of both qualitative and quantitative data. Among 240 sample villages, total 50 soil samples were acquired to examine soil quality from various villages. In this study, they illustrated three crop concentration zones for various crops. In zone one, they found that 14.19 per cent of maize crop was observed as greatest positive change and negative change was occurred in ragi crop during 2001-2002 to 2011-2012. In zone two, they found that 16.72 per cent of ragi crop was observed as highest negative change and greatest positive change was occurred in maize crop during this study period. In zone three, they found that 2.59 per cent of paddy crop was observed as greatest negative change and greatest positive change was occurred in coffee crop during 2001-2002 to 2011-2012 (Bindumathi, 2014). In order to condense the human influence on the natural resources and to classify the suitable lands in Hinglo river basin, Eastern India, a LSA using AHP was measured. The experimental results achieved for paddy cultivation is 10.88 per cent as highly suitable, 16.40 per cent as moderately suitable, 45.05 per cent as marginally suitable and 27.64 per cent as unsuitable. The western and north-middle portion of this watershed area is unsuitable for cultivation of paddy due to the lack of proper soil micronutrients, rugged topographic and risky climatic condition (Roy & Saha, 2018). The Koraiyar watershed study area used was classified into thirteen various land uses. The soil orders considered for this watershed area are 27.9 per cent (Entisols), 24.5 per cent (Inceptisols), 22.9 per cent (Vertisols), respectively. The author (Masilamani, 2016) stated that requirement of organic agriculture, new form of agriculture, micro level farming and mixed farming needed to be encouraged.

A study on previous research workers was highlighted in Table 3 for land suitability mapping of different Thematic factors like climatic conditions, LULC, socio-economic activities, soil/ water and landscape properties. Based on this work, a case study on sustainable land use planning of agricultural assessment in Ramanathapuram district, Tamil Nadu was focused on examining spatio-temporal changes in cropping pattern during 2005-2010 year and land use pattern during 1990-2010. In this work, it aimed to assess socio-economic activities in this study area for assessment of land use management of agriculture. They have classified the farmers on three bases: 47.4% are small farmers, 20.8% are marginal farmers and 31.8% are medium farmers. Over 88.8% land in this area was noticed as unirrigated method and 11.2% was noticed as irrigated land. Out of this 31.4% land was used as irrigated method for prosopis juliflora, while 68.6% land was used as unirrigated method (Devi,2014).

The work performed by author (Mandal *et al.,* 2020) recommended to use application of adequate soil reclamation, flood control, assured irrigation and number of fertilizers for finding supportable cropping systems. The main crops cultivated in this area are maize, vegetables and maize, where 70% of wheat farming was occupied for watershed areas of southern Iran. According to soil taxonomy, entisols, aridisols

Table 3
Previous studies based on LSM for different thematic factors

Previous Studies	No. of Factors	Climatic Conditions	Thematic Factors			
			Soil water and landscale propertoes		Socio-Economic Activities	LULC
			Physical	Chemical		
Zolekar, 2015	7	P, PE, AE, Rain water resource, Rainy season, T, RH & SH	MWHC, S, T, soil nutrients, SD, SM & SE	EC, OC, P, N & pH	Population, Literacy, No. of cultivators & landless labourers, market, cropping pattern, capital, land use, transport facility & per capita income	YES
Chozom. K, 2018	8	P & T	H, S, ST, A & Drain	-	Capital, Market, Transport, labourers	YES
Bindumathi, 2014	5	P & T	Soil Texture (BD) & S	EC, OC & pH	Population, Literacy Rate, Infrastructure Facilities, Sex Ratio Income, House Type, Irrigation, Land Holders, Education & Agriculture	YES
Devi, 2014	8	P, T, PAN Evaporation & RH	ST, S, Color, Soil Texture, Soil Permeability, Soil Reaction, D, R & GW	EC, P, N, M, pH, TDS, TH, SAR, RSC, Sodium in percent	Education, Religious Center, Entertainment & Culture, Population, Literacy, Market, Transport, Industries, Gross Area Cultivated, Farmers, Agriculture, Net Area Cultivated, Irrigation & Occupation	YES
Masilamani, 2011	8	P & T	S, Soil, D, Geo, R & G	EC, pH, SAR & TDS	Population, Irrigation, Literacy, Livestock, Sex Ratio, Occupational Structure, Transport	YES
Jamil, 2018	8	P	Soil Texture, SD, DR, DT, S, D, F & E	pH	Occupation Structure, Income, Agricultural loan, Availability of Farm Machinery, Irrigation,	YES
Purnamasari et al., 2019	8	P	S, H, Soil, NDVI, DR & DT	-	Population, Market & Productivity	YES
Zabihi et al., 2015	3	SH, GDD, RH, P, PR, Well & Spring,	A, S, Altitude	-	Population, DR	NO

Table 3 contd.......

Previous Studies	No. of Factors	Climatic Conditions	Thematic Factors: Soil water and landscale propertoes		Socio-Economic Activities	LULC
			Physical	Chemical		
Salas Lopez *et al.*, 2020	4	P, Min & Max T & RH	H, Tex, Terrain S & A	pH, SOM, CEC	DR, DW & PNA	YES
Orhan, 2021	4	PR, T, RH & SH	H, A, S & SD	-	Infrastructural and irrigation	NO
Tercan & Dereli, 2020	3	T, RH, SH & Pre	H, A &S	-	Infrastructural and irrigation conditions	YES
Iliquin Trigoso *et al.*, 2020	4	T, Pre	Tex	pH, N, P, K, EC, CEC, SOM	Land Use/ Land Cover, DR and PR	YES
Møller *et al.*, 2021	4	T, Pre	Drain, Tex,	pH	Population Sizes	NO

List of Abbreviations: SM–Soil Moisture, MWHC–Maximum Water Holding Capacity, OC–Organic Carbon, CEC- Cation Exchange Capacity, EC–Electrical Conductivity, SAR–Sodium Absorption Ratio, RSC–Residual, SOM – Soil Organic Matter, Sodium Carbonate, K – Potassium, M – Magnesium, N – Nitrogen, P – Phosphorus, pH - Potential of Hydrogen, AE – Actual Evapotranspiration, PE – Potential Evapotranspiration, TDS - Total Dissolved Solids, P – Rainfall, RH – Relative Humidity, T- Temperature, S – Slope, SH - Sunshine hour, H – Elevation, ST – Soil Type, Tex – Texture, Drain – Soil Drainage, Bulk Density - BD, A – Aspect, SD – Soil Depth, SE – Soil Erosion, R – Relief, GW – Ground Water, F- Flood, E – Erosion, DR – Distance to road, DW – Distance to Water, DT – Distance to town, D – Drainage, TH – Total Hardness, Geo – Geology, G – Geomorphology, Pre – Precipitation, GDD – Growing Degree Days, PR – Proximity to River, PNA – Protected Natural Areas.

and inceptisols are the most usual soil orders found in this region. Integration of fuzzy, GIS and AHP methods provided sustainable wheat cultivation for 48,306.6 ha (25.65%) of area as highly suitable (S1) class, 71,939.7 ha (38.2%) as moderately suitable (S2) class, 52,017.2 ha (27.63%) as marginally suitable (S3) class and 16,042.4 ha (8.52%) as unsuitable (N) class (Tashayo *et al.,* 2020).

In this method (Sahoo *et al.,* 2021), soils were arranged as IIItsf, IIsf, N1's and S3's based on irrigation and LCC suitability. Total 39 samples were acquired using several horizons of eight pedons and then sampling of horizon wise were carried out. The pedons were identified as suitable - moderately suitable for cluster bean and mustard, moderately - marginally suitable for forestry, pearl millet and gram, marginally suitable for wheat and cotton. For this study area, eight pedons were selected to represent four micro watersheds via Sainiwas (P3 and P4), Jhumpa (P5 and P6), Budhsheli (P7 and P8) and Motipura (P1 and P2) were studied in Bhiwani district of Haryana (2017).

LSI was computed for three approaches by varying three soil series. But for one soil series, the approach provided same results for maize, pigeon pea and cotton. The LSI correlation of crop yield found that MC-LSE performance showed better results than the two methods (Vasu *et al.,* 2018). Forty-seven per cent of results showed that total precipitation value during growing seasons is more significant than sixteen per cent of soil types. Thirteen per cent of accuracy were found important in case of soil pH and temperature. While three per cent and eight per cent of maize farming was found least importance in case of slope and elevation. According to these outcomes, it can be concluded that precipitation is most important for maize farming (Wanyama *et al.,* 2019).

The delineated landform/physiographic attributes were applied for creation of soil resources maps and 107 soil series are mapped with 96 mapping units. The result analysis found that 188439.4 ha (29.9%), 96213.3 ha (15.3%), 116671.7 ha (18.5%) of total area was highly, marginally and moderately suitable for cultivation of maize crop. Moreover, about 59267.4

ha (9.4%) of land area are permanently not suitable for maize production in the semi-arid region, India (Ramamurthy *et al.,* 2020). The work aimed to create a composite map for Zimbabwe province using weighted overlay analysis to understand how much percent of land is suitable for the sorghum and maize cultivation. From the Food and Agriculture Organization in United Nations, soil database was acquired to map all soil characteristics. Slope, depth, texture, organic carbon, Soil pH are factors considered in this study. About 0.5 per cent of area was found to be highly suitable (sorghum) and marginally suitable (maize) of total area 1936.42 km^2, 0.4 per cent of total area (1553.88 km^2) was unsuitable (maize) and moderately suitable (sorghum). The outcomes achieved is important in creating assumptions for crop planning could result in wrong decisions to be made (Muzira *et al.,* 2021).

Moreover, expansion of agriculture like conversion of grassland, wetland and forest requires an ecological cost. For 5.3 million hectares of cropland, about 10.6 per cent of crop land are distributed as S1, 32.0 per cent as S2,36.3 per cent as S3 and rest as un-suitable lands. About 42.6 per cent of crop lands cultivated are highly suitable or moderately suitable lands and rest are unsuitable and marginally suitable lands in Malawi (Li *et al,* 2017). From the land suitability analysis, it was further discovered that 24 per cent of the land is appropriate for soyabean and sorghum, where 15.29 per cent is suitable for sorghum and cotton, 24 per cent of land is suitable for citrus in the Seoni district. For 44.6 per cent part of the nonarable land is assessed for wildlife and forestry. 37 per cent of the land is suitable for grazing and forestry and rest of land is suitable(6.8 per cent) for wild life (Bhaskar *et al.,* 2015).

According to author (Al-Taani *et al.*, 2021), LULC classes was categorized into three main classes for three years (1990, 2000 and 2018) namely irrigated areas and forest has been fluctuated among 0.26 per cent (86.00 km^2), 0.32 per cent (108.06 km^2) and 0.31 per cent (102.68 km^2), built-up area was improved to 0.07 per cent (24.00 km^2), 0.13 per cent (41.88 km^2) and 0.21 per cent (68.66 km^2), while bare land was declined to 99.67 per cent (33366 km^2), 99.55 per cent (33476 km^2) and 99.49 per cent (33304.66 km^2) respectively. A study was conducted to deliver multi criteria assessment, AHP and GIS-based spatial decision-making system for considering the feed back and dependencies from local citrus experts and growers (Zabihi *et al.,* 2015; Tercan & Dereli, 2020). Based on land suitability analysis considering only physical factor, it revealed that paddy obtained 88 per cent as most suitable crop, followed by 85 per cent wheat crop, 84 per cent pulses and 83 per cent oil seed. Thus, 44 per cent of highest area was under moderately suitable class, trailed by 17 per cent highly suitable class, 25 per cent marginally suitable class, 10 per cent as currently suitable and 4 per cent as permanently not suitable for cultivation of crop in the Bijnor district (Jamil, 2018).

Two approaches were applied to assess LS: Most Limiting Characteristic Method (MLCM) and AHP with integrated climate and soil information on basis of FAO classification framework for apple cultivation. MLCM accounted 95.54 per cent for almost all areas were identified as unsuitable (N) and marginally suitable (S3) of land in Republic of Korea. Furthermore, AHP observed that majority of land had 34.1 per cent for S1 class and 44.17 per cent for S2 class (Kim & Shim, 2018). The authors (Chozom. K, 2018; Chozom and Nimasow, 2021) recommended that the study can also facilitates better understanding of choosing suitable area for apple cultivation and hence providing well opportunity for upcoming growth to horticultural sector. A study on Multi-criteria Analysis (MCA) based on spatial decision-making system are highlighted by considering the opinions from the local framers and experts. Ten exclusive and fourteen preference factors were analyzed for citrus farming. Approximately 80 per cent of area in this region includes slope, mountains, etc. Lemon, banana, strawberry and top five fruits like grape, olives, mandarin and orange are the most productive crops carried in Turkey. As a results, 1404766 ha (87.33%) was determined in unsuitable and 203806 ha (12.67%) of this classification was occupied as suitable for citrus cultivation (Orhan, 2021).

A case study for sites election of LSA and physical planning using MCDM and GIS was evaluated in Turkey region to pistachio cultivation was proposed to support the environmental protection and assist in future land-use rules (Everest, 2020). Agricultural LSE for the production of wheat crop in Patan district of North Gujarat, India was employed using spatial MCDM approaches. The purpose of this work is to analyze the specific crops based on spatial distribution and provide policy makers and decisions for sustainable agriculture to meet necessary requirement. The performance results obtained for the study area is 34.09 per cent of land area were highly suitable, 47.37 per cent of the land were moderately suitable, 11.76 per cent of the land were marginally suitable and 6.76 per cent of the land were unsuitable (Dadhich *et al.,* 2017).

A novel case work was explored to find the Land Suitability for present agricultural land on basis of organic farming in the North Carolina region for production of rainfed wheat by classifying seventeen groups from five major group using MCDM, square root and GIS (Karimi *et al.*, 2018). Several number of research work were carried out in Ethiopia regions to detect potentials and limitation of LS areas for making decisions on different crops like wheat and barley (Yohannes and Soromessa, 2018; Fekadu and Negese, 2020), teff production (Kahsay *et al.*, 2018), sorghum (Kahsay *et al.*, 2018; Tadesse and Negese, 2020), wheat, barley and faba bean (Girmay *et al.*, 2018).

Land assessment procedure is based with the calculation of land potential and routine for precise utilization of land type. The experimental results illustrated for sugarcane cultivation is 7 per cent is marginally suitable, 8 per cent as unsuitable, 24 per cent is moderately suitable and 61 per cent is highly suitable. Overall, 7 per cent of area were not suitable for cultivating sugarcane in Bijnor district. Fuzzy AHP provides advantages of basic AHP in handling multi combination and criteria of data that involves both qualitative and quantitative methods. AHP decline ambiguity and use uncertainty to create decisions with help of pair wise comparison matrix. Fuzzy AHP is a promising tool used in agricultural activities, whenever complex decisions are to be considered (Jamil *et al.,* 2017). The general objective of this study is to apply AHP, GIS and Fuzzy set method to evaluate LS to maize and wheat production of area (5474.27 ha) for calcareous and saline soils situated in semi-arid provinces of Iran. According to results analysis, 0.221 highest weight value were achieved for soil texture and 0.012 lowest weight value were achieved for negotiable sodium percentage.

The results indicated that 803.75 ha (14.68%) of studied area was highly suitable, 4282.53 ha (78.23%) of area was moderately suitable and 387.99 ha (7.08%) of area was marginally suitable for production of wheat, respectively (Reza *et al.,* 2020). An LSM using AHP and fuzzy was implemented using spatial analyst tool to extract tobacco zones in twenty-two countries of Shandong provincial using DEM. In case of climatic conditions, 6389.80 km^2 (65.12%) of total land area was highly suitable, while considering the soil nutrient factors, 42.8 per cent of total land area is highly suitable and 19.66 per cent is unsuitable for tobacco production (Zhang *et al.,* 2015). Three standardized criteria method like stepwise, linear and fuzzy were assessed for soyabean LS computation. About 0.8438 coefficient value was determined using fuzzy standardization method with integration of climate and soil factors producing more precise suitability values (Radocaj *et al.,* 2020).

Fuzzy membership function and Analytical hierarchy process was used for handling numerous heterogeneous factors. Twenty-two soil sample profiles were collected from twenty-two various land units. The restrictive factors affecting growth of teff crop are slope, length of growing period and available phosphorus is about 5.42, 56.99 and 37.59 per cent of accuracy. Additional studies involving socio-economic variable should be recognized to enhance outcomes of land suitability. Since only biophysical parameters are considered in this study (Kahsay *et al.,* 2018).

A literature search was conducted out to examine if more research articles has been published for LSM based on various regions of agricultural pratices in recent years. The Web of Science databased reasearch papers were only considered for employing literature search with keywords or topics involving agricultural productivity, farming, site selection, land use planning, soil informatics, hilly regions, coastal regions, semi-arid regions and watershed regions with time span of eight years (2014-2021). The searched outcomes were further validated to ensure that all publications comes within the scope of land suitability mapping for crop production. About 49 per cent of articles were published for LSM on basis of agricultural productivity and only 2 per cent of publications was carried out for farming potential as shown in Fig. 3. The present study was used as a scoping approach to attain and gather geospatial information on LSM for agricultural crops species. Robust methods are very important to develop LSM to enhance existing and further planning on land use/ land cover, socio-economic and physical factors, landscapes, soil properties (physical and chemical), climatic conditions and guidelines on production of crops. From the literature review, it is suggested that the decision makers or research scholars to use robust system and standard attributes for analyzing land suitability in the crop productivity.

The review conducted to examine the present state-of-art in fields of geospatial technology using Remote Sensing satellite data, GIS, Machine learning applications for Land Suitability Mapping in crop production and its future trends. Different analytical approaches like Support Vector Machine, Linear regression, Random Forest, basic machine learning techiques have been employed in existing literature for assessing information in geospatial technology for examining different land suitability features. Previous studies have commonly used the AHP, Fuzzy, WOA, ANP approach, while more advanced machine learning, regression, deep learning methods have been less explored. Several analytical methods have different merits and limits and thus it is essential to compare such methods for particular research (e.g., accuracy requirements and computational efficiency) and select an optimal techniques. Methods for enhancing the determination of LSM using RS data involving use of ancillary data, multi-temporal imaging and these approaches holds true across all the spatial scales. Therefore, quantitative and qualitative method must be used by integrating it into hybrid land assessment method to optimize the LSM.

In conclusion, land suitability mapping with remote sensing data is challenging but possible. As with several RS problems, accurate results may require methods for specific place on a case by case basis. Besides, previous studies using optical remote sensing and GIS applications have been targeted for investigating land suitability for crop growth (*i.e.,* aiming to enhance crop yield), while less research has been focused on hyper spectral imaging for understanding and analyzing LSM for crop production. Further research work in these areas must be warranted. The significant part is to have knowledge of what to produce in several area for adaptation and to select variety of crop during changing seasons might be precautions to strengthens the food insecurity. With use of present and future machine learning methods and hyper spectral satellite data in LSM can provide a way for sustainable food security and agricultural areas.

In order to achieve better results and performance analysis for assessment of land suitability, dataset collected should be in up-to-date order. If provided dataset is analyzed with unreliable data in GIS, then it results to unsuccessful performance evaluations. Hence, to avoid such issues, expert opinions should be taken from different sources and converted them into the model. Further, the generated maps can be released in online website or through mobile/ desktop applications. Hence, better assessment of plant-soil relationships and planning can gain significance in recent decades. In upcoming days, it is necessary to consider the data with finer resolution to optimize accurate mapping. Hence, it might help to improve the delineation of LS in marginalized agricultural community that are referred to be highly heterogeneous. As further recommendations, some other data sources like native vegetation, underground water level, historical yield information and irrigation

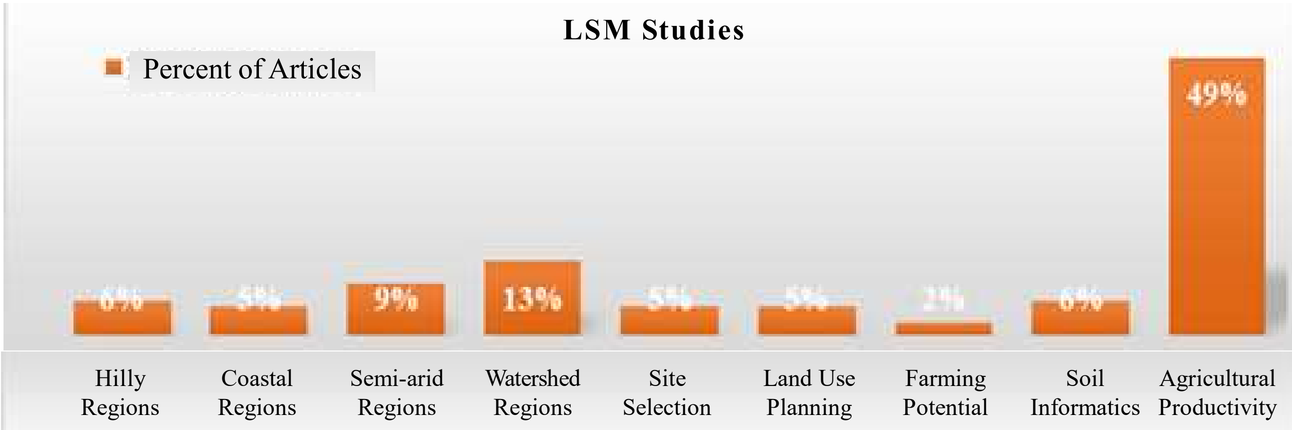

Fig. 3: Percentage distribution of research articles published for land suitability mapping from 2014 to 2021 years.

records can be used in some of analytical methods (e.g., advance machine learning and deep learning) as a additional ancillary data for better assessment of crop features. More research in these areas are also to be warranted.

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