A Review of a Methodological Framework for agricultural Suitability for Assessment

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Abstract
Agricultural suitability, which takes into account several aspects like topography, soil quality, climate, accessibility to water, and appropriateness for specific crops or livestock, is the area's capacity to support agricultural activity. Crop production yield per unit area increased as a result of the industrial and green revolutions, there was the development of new methods, tools, and techniques that were used for modern agriculture systems. During this period the use of chemical fertilizers and pesticides was also increased to boost production,but it didnot develop good plant characteristics such as a good root system, shoot system, or nutritional characteristics whichcaused health problems.The excessive use of these chemicals decreases the soil and water suitability for irrigation. Farmers nowadays use chemical fertilizers in agriculture to increase production, but they are unaware of the impact these fertilizers have on their health, water, and soil quality. This review paper highlights the agricultural suitability and the study of the researchers in which they assess the groundwater or surface water suitability and soil suitability in irrigation and the effect of chemical fertilizers on the environment, Human health, and on ecosystem.

Keywords: Agriculture, Chemical Fertilizers, Environment, Human Health,Land Cover and Land Use, Water Suitability, Soil Suitability.

INTRODUCTION

In India, agriculture is one of the main sources of livelihood for about 58% of the Indian population. About 65% of the total population lives in the villages and about 48.9% of its population depends directly or indirectly on agriculture to obtain their income (Economic Survey, 2018). It is well-known that the soil on which crops are grown is directly impacted by the quality of the irrigation water. The need for agricultural products and land has increased dramatically during the past century as a result of population growth. Experts from all fields have also concurred that environmental pollution, urbanization, industrialization, and inadequate land management place additional strain on agricultural output. The reduction in the quantity and quality of water available to irrigate these lands, as well as the reduction in the amount of land suitable for agriculture, can be attributed to all of these reasons. The salinity issue that many people face is a striking illustration of this phenomenon of the relationship between soil and water quality.

REVIEWS ON WATER SUITABILITY FOR IRRIGATION PURPOSES

Several problems, including urbanization, industrialization, environmental degradation, and poor land management, harm agricultural production, which has increased dramatically as the population has grown. These elements are to blame for the decline in the amount of agricultural land accessible as well as the quantity and quality of water needed to irrigate these farms (Tanji, 1990; Kwiatkowski, et al., 1995).Pure water is a poor conductor of electricity and acids, basic, and salts make it a better conductor. Such substances are termed electrolytes. The ones with poor solubility are known as weak electrolytes and the ones with higher solubility are known as strong electrolytes. Thus, the higher the concentration of electrolytes more the electrical conductance. The conductance of distilled water is 1 to 5 µS. Water up to 20µS is considered suitable for irrigation. Since theconductivity varies with temperature it is reported at 25°C (Saxena, 1990). Groundwater is almost presenteverywhere below the surface of the earth, which can be found in thousands of small aquifer systems in addition to one large aquifer. The availability of water in sufficient numbers and of high quality is essential for many of man's activities, including food production and nutrition (Howari et al., 2005). Nowadays manyhuman activities as well as natural factors are affecting the quantity and the quality of this valuable resource (Jain et al., 2010). If there is no freshwater of adequate quantity and quality, sustainable development is not possible (Kundzewicz, 1997). Horton (1965) was the first person who propose the modern Water Quality Index and several studies were done in this field by using this method (Abbasi and Abbasi 2012; Abtahi, et al., 2015; Bouguerne, et al., 2017). Many researchers have recently investigated making numerous changes to the WQI concept. (Bhargava & Saxena, 1990; Dwivedi, et al., 1997). For the prediction of the Water quality Index Hameed et al.,(2017) applied artificial intelligence techniques, and Najafzadeh et al.,(2018) used a computer-based formulation for predicting the water quality parameters. Misaghi et al.(2017) for irrigation purposes established the first systematic Water Quality Index (WQI)which was based on the NSF-WQI. To account for qualities suited for irrigation, water quality parameters were modified and as per FAO 29 guidelines a weighting chart was generated. It is necessary to create a region-specific water quality index (WQI) since the quality of the water used for irrigation differs from one area to the next and is influenced by several factors, including plant traits, soil quality, and local and climate conditions. When evaluating water quality, physical and chemical parameters are important factors to consider but analyzing these factors individually doesn't provide a clear picture of the water quality (Orozco et al., 2017). The Groundwater geochemical studies have improved our understanding of potential quality changes (Bouderbala, 2017) and these studies incorporate a variety of physical and chemical variables to create a water quality index (WQI), which is a single number that represents the level of water quality and is derived from a wide range of water parameters (Patrick & William, 2013).Tyagi et al.(2013) believed that this process is more understandable and easy to evaluate the water quality and also the potential risk of the water body which was based on various parameters. The Water Quality Index also assesses the quality of groundwater in arid and semi-arid regions as it consistsof a numerical and mathematical method (Alobaidy, et al., 2010; Ramakrishnaiah, et al., 2009). Brown et al.(1970) developed a general WQI which was based on the weights of the individual parameter. Filipovic (2002) found out that for irrigation purposes about 2,500 km^3 of water all over the worldis consumed annually. Nearly 70% of the 982 km^3/year of groundwater extracted globally is utilized for irrigation. There are three major countries dependent on groundwater extraction namely, India, China, and the United States. In India, for irrigation, about 90% of extracted groundwater is used, which accounts for nearly, 251 km^3/y (Margat & Gun, 2013). Zekster et al.(2005); and Singh and Kasana, (2017)when groundwater extraction exceeds natural recharge, groundwater levels drop, which has several adverse impacts on the growth of agriculture in irrigated areas. Bajwa et al. (1983) in arid and semi-arid regions the groundwater mainly contains a high concentration of solute salts. A high amount of carbonate and bicarbonate of sodium is present in the groundwater which is used for irrigation and continuously using this water will increase the salinity and exchangeable sodium in the soil (Bajwa et al., 1983). In the maintenance of crop development and growth and their yieldsNa^+, Mg^{2+}, $Ca^{2+,}$ and K^+play a great role. Sodium hazards affect the crop's ability to absorb water from the soil by decreasing soil permeability. In the summer, as the osmotic pressure drops, fewer water molecules can reach the branches and leaves (Tahmasebi et al., 2018; Xu et al., 2019). Gypsum can be used to reduce the effect of salinity from soil (BIS 2012).The amount of sodium absorbed by the soil is significantly correlated with the irrigation water sodium adsorption ratio (SAR). The physical condition and the texture of the soil are affected if the concentration of Na^{2+}saltsis high in the soil (Nagarajan et al., 2010). To evaluate the water quality for irrigation of the *Simav Plain* in Turkey, Simsek & Gunduz (2007) developed a GIS (global information system) which was based on the irrigation water quality index (IWQI). They discovered that the surface aquifer's local groundwater quality is generally suitable and that the aquifer water is best appropriate for irrigation through the combination of well-known hydrochemical characteristics (Simsek & Gunduz, 2007). Ahmed et al. (2010) analyzed the both surface and groundwater quality of greater Chittagong of Bangladesh and identified the arsenic problem in the study area by using various Physicochemical and microbiological parameters (Ahmed et al., 2010).Rock leaching in agricultural drainages and weathering have a significant impact on Al-Wehda's water quality. A variety of water quality parameters have been used to assess the quality of water during the summertime when the demand for water for irrigation purposes increases. After analyzing the parameters Na% and TH it was found that the reservoir water is not suitable for irrigation purposes. (Al-Tanni, 2013).The groundwater suitability for irrigation purposes has been assessed by using several water quality indices and geo-statistical modeling with spatial mapping of water quality in the Faridpur District located in Central Bangladesh. In groundwater samples they examined the cation abundance in the following order: Ca^+>Na^+>Mg^+>K^+ and the primary anions were HCO_3^-> Cl^- > SO_4^{2-}. It was found that 30% of the samples had low suitability for irrigation purposes while the remaining 70% of the samples were highly suitable for irrigation which shows that the groundwater of the study area was permissible for irrigational uses (Rahman et al., 2017).By using the water quality index (WQI) the quality of theKashkan River was evaluated. During 36 years (1974-2009), measurements from 10 sample stations were used to create the Canadian Council of Ministers of Environment water quality index (CCME WQI) approach. The measurements included electrical conductivity, pH, cations (Na^+, Ca^+, M_g^{2+}) and anions (HCO_3^-, Cl^-, SO_4^{2-})(Mostafaei, 2014). Rezaei & Hassanni, (2018) studied the area of Isfahan in Iraq, the samples were tested and analyzed through the Gibbs diagram. The pH value ranged from 7.05 to 8.95 risk assessment and irrigational suitability are assessed through electrical conductivity (EC), sodium percent(% Na), sodium adsorption ratio(SAR), and residual sodium carbonate (RSC)(Rezaei & Hassanni, 2018).A study was conducted in Tirupati region in the Chittoor district of Andhra Pradesh to analysis the groundwater, and the major ions in most of the locations were to be found within the permissible limit, and the groundwater is capable of drinking and irrigational purposes except for a few samples. Sodium is the most dominant ion, few of the samples cross the sample limit, which was because of the interaction of the groundwater with sewage and the intensive agricultural practices (Balaji et al., 2017).By using sodium absorption ratio SAR, Percent Sodium (Na%), residual sodium carbonate (RSC), permeability index (PI), soluble sodium percentage (SSP), Magnesium ratio (Mg), Kelly's Ratio, and Magnesium Hazard, (Hwang et al., 2017) worked on the cations and anions for groundwater quality assessment (Hwang et al., 2017). Hydrogeological field studies were performed in the Wet Pampa Plain, Argentina from 2005 to 2010. An irrigation water index (IWI) is calculated by combining variables such as electrical conductivity (EC), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), slopes, and hydraulic gradient. An aquifer thickness and the appropriate classes from the IWI are then integrated to create a restricted water index (RIWI). According to the IWI index, 31.4% of the land has inappropriate water while 61.3% of the region has "very high" to "moderate" irrigation potential. So, irrigation planning is necessary for effective practice in the region since about 46% of the examined area has high suitability for irrigation and moderate groundwater availability, and the RIWI in the tested area is the "2" with high appropriateness for irrigation and moderate aquifer potential (Romanelli et al., 2012).The groundwater suitability for drinking and agricultural purposes was evaluated by the water quality index (WQI) in the plain of the Upper Cliff, Algeria. The Parameters such as electrical conductivity (EC), sodium absorption ratio(SAR), residual sodium carbonate (RSC), Kelly's ratio (KR), magnesium adsorption ratio (MAR), permeability index (PI), sodium percentage(%Na), and chlorine (Cl)indicates that in the study area the groundwater quality varies from good to unsuitable for irrigation purposes (Bouderbala, 2017).

Soil Suitability for Agricultural Suitability

The high concentration of fertilizers including potassium and high levels of sodium hurts pH, soil structure deterioration, and the growing prevalence of acid irrigation and other agricultural practices. If acid-forming nitrogen fertilizers continue to be used by preventing field crops from becoming less productive, the pH of the soil will gradually decrease, causing liming. Fertilizers are normally applied to increase the yield of the crop (Luo et al.2015). In Bangladesh, Baluka is an emerging industrial town and 15 samples were collected and tested for soil pH, electrical conductivity (EC), organic matter (OM), nitrogen (N), phosphorus (P), potassium (K), sulphur (S), sodium (Na), lead (Pb) and cadmium (Cd). The silt content was found higher at the discharge point (Tabassum, et al., 2016). Massah et al. (2016) studied the effect of fertilizers that resulted in soil degradation and compaction and the research was conducted on 12 wheat farms in the Pakdasht region which is located 35 km southeast of Tehran and the average annual precipitation at this site is 210 mm. An electronic Penetrologger was used to measure the soil penetration for sample collection from 12 wheat fields at a depth of 0-30 cm.After analyzing the data, Duncan's multiple range tests were used to compare the mean value of the data. The result shows that soil compaction reduced yields by 40%, accessible water by 34%, and permeability by 81.4%. Thus, fertilizer application results in the production, buildup, and concentration of fertilizer mineral salts, which over time causes the soil to degrade and produce a compaction layer. High compaction increases bulk density and resistance to soil penetration while lowering porosity and aeration (Massah et al., 2016). In Ismani which is situated in Iringa, Tanzania, the production of maize diminished rapidly in the 1990s and the primary cause of this was long-term chemical fertilization, which increased the pH of the soil and caused the soils to become more acidic. The acidic soil reduced the amount of nutrients available to plants and increased the amount of toxic metals in the soil. It also has an impact on the existence of microorganisms like earthworms which produce humus that is beneficial to crop development (Mkonda, 2017). To identify the urea in the soil a simple colorimetric method was developed. The soil sample was extracted with 2M KCl including phenyl mercuric acetate, a urease inhibitor. The extract urea content was determined by measuring the red color that developed an aliquot and a part of it was heated in an acidic solution containing diacetyl monoxime and thiosemicarbazide. By using steam distillation methods, the extraction conducted was adequate for the detection of various anions such as exchangeable ammonium, and nitrite. This method provided quantitative recovery of urea supplied to soils (Douglas et al., 1970). To study the transformation of nitrogen fertilizers in the soil laboratory experiments were carried out. For this, fresh soil was collected from 0 to 7.5 cm depth at 14-day intervals. The result shows that nitrification in the soil was twice as rapid compared to other types of soil (Ellis et al., 1978). It has been stated that West Bengal's agricultural soils and chemical fertilizers contain naturally occurring radioactive. Soil samples were taken from the cultivated land's surface to measure the alpha activity. The sampling sites were selected randomly. The outcome demonstrates that these fertilizers and soil sample alpha activities ranged from 109 Bq/kg to 660 Bq/kg and from 141 Bq/kg to 2,589 Bq/kg. These results were used to determine the direct chemical fertilizer application's contribution to the health effects of environmental radiation exposure on humans(Ghosh et al., 2008). Lungu et al.(2008) demonstrated that the annual burning of stover on the land is unlikely to decrease the acidification associated with this urea treatment. Instead, the long-term yearly applications of urea caused soil acidification and lowered the amount of exchangeable bases in the soil. Anu et al.(2010) assess the soil propertiesof the soil samples that were taken from Bhopal's Shahpura Lake. Theyconcluded that pollution in and around the wetlands of Bhopal City wetlands had an impact on the quality of the water and soil. Decreasing soil quality was caused by untreated sewage and urban waste and harmful substances from the soil and water penetrating fruits, vegetables, cereals, and other food items, eventually making their way into human diets and causing several diseases(Anu et al., 2010).Bhat et al.(2011) investigated urea hydrolysis in saturated loamy soil to assess the amount of urea fertilizers loss as a result of urease-catalyzed hydrolysis. The maximum size of the soil particles was limited to 2 mm. A batch trial was carried out using varying soil urea concentrations and it was saturated and incubated for 48 hours at 27°C. The evolved gasses were allowed to escape in order to prevent the enzyme from becoming inactive at high pH levels. The colorimetric method was used to estimate the amount of urea. The findings show that the urea content in soil extract could reach 43.6 ppm and that the rate of hydrolysis increased as the initial urea concentration increased. Because of substrate-induced inhibition, the urease-induced hydrolysis was deactivated at concentrations of 305 mg/mL and above.

Agricultural Land Cover and Land Use

The Land is one of the important resources which is required by human beings and other species on earth for a living. The changes which are induced in the landscape are a function of demand. According to the 2012 prospects of the world population,the United Nations was 7.3 Billion in mid-2013. It further projected the world's population to be 8.1 billion in 2025 which is an increase of 11%. There shall be an overall decrease in the population of central cities and a tremendous increase in the periphery. The phenomenon of population growth could be seen as suburban growth rather than city growth. Ultimately it is the demand of the population that is creating changes in the landscape (Ahlquist et al., 2016). To maximize the utilization of the area of the land for a particular purpose, the suitability of the land is evaluated concerning the suitable cropping system (FAO 1976; Sys et al., 1991). Land cover refers to the biophysical characteristics of the land surface whether constituted of natural components. It can be mapped as discrete variable units such as forest, shrubland, and wetland or continuous units such as canopy cover. The land cover system directly interacts with the earth system processes such as energy transfer, water cycle, energy cycle, etc. The use of land by humans is known as land use. It is a result of human activity that derives significance from activities and land assessment. Like the land cover, land use can be either of a discrete type such as agriculture, human settlements, or levels of use like high, medium, and low-density residential areas (Brownet.al., 2013).Suitability is a function of crop requirements and land characteristics and evaluates how well a land unitmeets the basic requirements of a particular type of use (FAO 1976). Land suitability analysis (LSA) is a method by which one can find the existing and potential capabilities(Bandyopadhyaya et al.,2009). The land evaluation measures the degree of land usefulness for possible land use by land requirements and attributes (FAO 1976; Hopkins,1977; Malczewski, 2004). The development of Multi-Criteria Decision Making (MCDM) or Multi-Criteria Evaluation (MCE) aims to improve spatial decision-making in situations where a set of alternatives must be assessed by using criteria that are unsuitable and conflicting (Malczewski, 2006) and it attempts to explore many options considering several criteria as well as multiple goals (Carver, 1991). For land suitability study, the Multi-criterion evaluation (MCE) method is primarily utilized. In the decision-making process to solve the various land problems with multiple alternatives, multi-criterion evaluation of land suitability involves different criteria such as geological and biophysical elements (i.e., geology, soil characteristics, relief, atmospheric conditions, vegetation, etc.) as well as the economic and socio-cultural conditions (Joerin et al., 2001) to solving the different land problems with multiple alternatives (Wang et al.,1990; Jankowski, 1995; Yu et al., 2011).The Geographical Information System (GIS) is a useful technique to investigate multiple geospatial data with precision and higher flexibility in land suitability analysis (Mokarram &Aminzadeh, 2010; Mendes& Delali, 2012). To create the site suitability model for agricultural growth, the analytical hierarch approach applies a variety of criteria maps that are created using GIS techniques (Xuet al., 2012). Recently, someGIS-based land suitability analysis approaches have been developed, including modeling and Boolean overlay. However, these approaches lack a clear mechanism for integrating the preferences of the decision-maker into the GIS procedures. This problem could be resolved by combining Multi-Criteria Evaluation (MCE) methods with Geographic Information System (GIS) techniques (Malczewski, 2006). In the Guang Bdiyasub-catchment in the Abhaya district agricultural land suitability for for the sustainable production of crops was assessed. Assessment of soil and slope parameters were the steps to evaluate the concerned research problem, soil samples were analyzed for pH, texture, electrical conductivity (EC), top and subsoil, stoniness, salinity, pH, carbon exchange capacity, exchangeable sodium percentage, and organic matter. The slope suitability map is derived from a digital elevation model (Dent &Young, 1981). The soil's pH ranged from 5.6 to 6.3 and sodicity varies from a minimum of 0.18% to a maximum of 1.88 %. In terms of slope suitability, FAO guidelines have been used (Kebede &Yonas, 2016). Kant et al.(2009) analyzed the role of land use and land cover changes on vegetation density and surface temperature while using the multispectral LANDSAT-7 ETM data, they concluded that at the city level, land use and land cover had an immense influence on the temperature regime. According to the Indian State of Forest Report 2017, 8 land utilization classes were made for Rajasthan Land Use Mapping. The forest area occupies 8.05%, not available for land cultivation 12.47%, permanent pastures 4.94%, land under miscellaneous tree crops 0.07%, culturable wasteland 11.67%, Fallow Land other than current fallow 5.39%, net sown area 53.32% (Indian Forest State Report 272).

Impact of Chemical Fertilizers on Environment and Human Health

Savci, (2012) that chemical fertilizers are absorbed by plants through the soil and can subsequently enter the food chain and may affect the heavy metal concentration in the soil and plant system. It leads to water, soil, and air pollution. Before applying nutrients to the soil an in-depth soil analysis should be carried out. Panin et al. (2019) worked on the impact of the overuse of fertilizers on the environment in Serbia. It was found that 79.79% of farmers use chemical fertilizers and mostly use fertilizers such as – *KAN, AN, Urea, and NPK* 15:15:15 and 66.6% of farmers do not know the harmful pollution effects of nitrates on soil and water and are unaware of its harmful impact. Namdev et al. (2011) invested that the application of chemical fertilizers like urea, DAP, sulphate phosphate, etc. has resulted in a higher concentration of phosphate and nitrate in the water samples as well as a higher concentration of nutrients being available in the low water of the Hathaikheda reservoir in Bhopal. Tudi et al. (2021) pesticides are useful in lowering disease rates and raising crop yields, their improper use and management can have negative effects on both the environment and human health. Controlling the use of pesticides is therefore essential due to their detrimental impact on the environment, human health disease, and non-target creatures(Tudi et al., 2021). Chemical fertilizers improve plant growth and strength. Nonetheless, plants produced in this manner do not acquire excellent plant features such as root structure, shoot structure, and nutritional values. They will not have enough time to grow and mature properly (Kumar et al., 2019). According to FAO (2009), Turkey utilizes fewer chemical fertilizers than many other developed and developing nations. The amount of chemical fertilizers (N+P+K) used per hectare in this area is estimated to be 100.4. The Netherlands has 665.5 kg/ha, Egypt 624.8, Japan 373.2, China 301.5, Britain287.5, Germany 205.4, France 180.1, United States160.8, Italy 126.4, India 121.4, Greece 115.4 and 106.9 in Indonesia kg/ha (FAO, 2009). In the Maldives, fertilizers and insecticides are being imported and used more frequently. According to the Maldives National Chemical Profile, insecticides were the most commonly imported pesticides between 2010 and 2014. The overuse of fertilizers leads to several environmental issues as well as health issues including cancer. It is critical to raise farmer's awareness and improve their technical skills (Ajila, 2021). Chemical fertilizers reduced the soil's fertility and rendered it unfit for crop plant growth. But biofertilizers are efficient and environmentally friendly. They activate the soil's natural microorganisms to restore the soil's fertility and protect against drought and soil diseases. They also cause many environmental hazards, such as soil erosion, water contamination, pesticide poisoning, falling groundwater tables, water logging, and biodiversity loss (Suhag, 2016).). Sethy & Ghosh, (2013) heavy metals such as Pb, Cd, Ni, and Cr are significant environmental pollutants that have toxic effects on plants, reducing productivity and posing serious risks to agroecosystems. They also act as stressors on plants, affecting their physiology, and exposure to Pb and Cd can have negative effects on human health when consumed in vegetables and other crops (Iwuanyanwu & Chioma, 2017; Hussain, 2004). In Nepal, seven types of fertilizers are used in high quantities i.e Urea, Diammonium Phosphate (DAP), Murata of Potash (MAP), Ammonium Sulphate (AS), Single Super Phosphate (SSP), Ammonium Phosphate Sulphur (APD) and NPK and its consumption is 19.65 kg/ha in 2004/2005 (Diwakar et al., 2008). In the North 24 Parganas in West Bengal, about 70% of farmers use chemical fertilizers and 30% avoid chemical fertilizers for their cultivation purposes (Roy et al., 2015). Investigating farmer's knowledge of pesticide residues and their practices when applying pesticides is crucial to minimizing human variables that compromise agricultural safety (Hou & Wu, 2010). Between 2002 and 2007, the amount of fertilizer used per hectare grew by around 30% or 95 tons. About 24% of the nutrientsare nitrogen, P_2O_5, and K_2O. Overuse of chemical fertilizers negatively affects crop development and soil health (Iqbal, et al., 2020).

Conclusion

These chemical fertilizers have many harmful impacts on our environment as well as on living beings. In addition to the use of chemical fertilizers, organic farming will create a healthy, natural environment and ecosystem for the present as well as for future generations. The negative effects of this chemical on human health and the environment can only be reduced or eliminated by adopting new agricultural technological practices such as shifting from chemical-intensive agriculture. This includes the use of organic inputs such as manure, bio-fertilizers, bio-pesticides, and slow-release fertilizers with improved application and use efficiency.

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