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Agroecological Zoning for Lemongrass (*Cymbopogon flexuous* Stued Wats.) Cultivation in Haryana

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Abstract

Agroecology as a practice integrate ecology with agriculture. It provides scientific basis for the cultivation of medicinal and aromatic plants (MAPs) for overall conservation, management and development, environmental sustainability, health and economic development. Every region with its unique natural and geographic conditions has potential to supports different species and varieties of crops and plants. These potentials should be properly utilised for natural resource development. The approach of agroecological zoning is a method to realise this goal. Modern science of geoinformatics which combines different disciplines and technologies dealing with spatial information has made it possible to delineate these zones where these plants may be suitably cultivated and conserved. In the present paper, agroecological conditions (environmental, pedological and agricultural) of cultivating lemongrass in Haryana have been studied using these technologies and statistical techniques. The agroecological requirements or sets of potentials and constraints (land, soil and environmental characteristics) for the cultivations of lemongrass have been used to identify zones/regions of varying suitability in GIS environment using IDW interpolation method of Spatial Analysis kit in ArcGIS 10.3. This exercise has resulted into four zones of different levels of suitability found on the basis of average expected yield of the plants in different locations of the state.

***Keywords**: Agroecological regions, Agroecological zones, Crop suitability, Lemongrass cultivation, Aromatic plants*

INTRODUCTION

This study attempts to demarcate the agroecological zones for the cultivation of lemongrass (*Cymbopogon flexuous* Stued Wats.) in the state of Haryana where this plant can establish and realise its full genetic potential for commercial benefits. Agroecological zoning approach is a little different from ecological zoning in its methodology in that agricultural resources, the resources developed by human agency as irrigation facilities, soil fertility boosting techniques or practices etc. are superimposed upon natural conditions (Food and Agriculture Organization FAO 1978). An agroecological zone is the land unit carved out of agroclimatic zone superimposed on agricultural resources developed by humans and landforms which act as modifier to climate, availability of moisture and length of growing period. Thus, an agroecological zone is a homogeneous land unit in terms of climate, length of growing period (LPG), soil properties and physiographic conditions which are suitable for certain group of plants with agricultural resources developed by humans (FAO 1983, Martin and Sauerborn 2013:7).

Agroecological method is very useful in the "identification of areas with specific climate, soil, and terrain constraints to crop production; estimation of the extent of rain-fed and irrigated cultivable land and potential for expansion; estimation of crop production and yield; evaluation of land potential for crops cultivation and diversification; regional impact and geographical shifts of agricultural land and productivity; determining plant suitability for optimization of land use; study of potentials and implications for food security resulting from climate change and variability" (Fischer *et al.* 2006, Gliessman 215:18).

There are different methods and schemes of determining agroecological zones for different crops, plants and regions. FAO (1978) in its scheme to demarcate world into different agroecological regions used mean growing period temperature and length of growing period, determined by annual precipitation, potential evapotranspiration and the time required to evapotranspire 100 mm of water from the soil profile. Consultative Group on International Agricultural Research-Technical Advisory Committee, CGIAR-TAC, used mean annual and growing period temperature, and length of growing period (determined the same as in the FAO zonation scheme) (Sivakumar and Valentin 1997). The Global Agro-ecological Zones GAEZ uses temperature, precipitation, potential evapotranspiration and soil characteristics (Fischer *et al.* 2012). Harvest Choice Agro-ecological Zone, HCAEZ used mean temperatures, elevation, and GAEZ-LGP are used to define thermal regimes and temperature seasonality. Scheme of Global Land Initiative GLI includes Harvested area of target crop, crop-specific GDD and soil moisture index (actual evapotranspiration divided by potential evapotranspiration) (Mueller *et al.* 2012). Global Environmental Stratification GEnS has used four variables (Growing degree days GDD with base temperature of 0 ◦C, an aridity index, evapotranspiration seasonality, temperature seasonality) used in iso-cluster analysis to "cluster" grid-cells into zones of similarity (Metzger *et. al*. 2013, Warta *et al.* 2013).

The agroecological approach has also been adopted by the ICAR and National Bureau of Soil Survey & Land Use Planning (NBSS & LUP) in India to divide country into 20 regions (ICAR NBSS & LUP 2015). Subramaniyam *et al.* (1984) and Chowdhary *et al.* (1989) demarcated agroecological zones of Punjab and West Bengal, respectively. Gajbhiye and Mandal (2000) studied agro-ecological zones, their soil resource and cropping systems in India. Zaidi (2011) studied agroecological suitability of cultivating select medicinal and aromatic plants in the state of Haryana, India.

Since, production is the bottom line of all production systems so is with agricultural systems. All environmental, pedological and agricultural factors finally affect yield and production of crops. Therefore, in the present analysis expected yield (calculated for selected locations of the state) of lemongrass has taken as the sole criterion for the process of defining agroecological zones at different levels of suitability as it reflects not only environmental potential and constraints but also level of agricultural resources (irrigation) developed by humans for the establishment and growth of plants (Zaidi 2011).

ABOUT STUDY AREA

The state of Haryana is located between 27º 39 'N to 30º 55 'N latitude, and from 74º 27 'E to 77º 36 'E longitudes. The state covers an area of 44,212 km^2 and accounts for about 1.35 per cent of the geographical area of the country. Almost 80 percent of its land area is under cultivation mostly under wheat and rice. As per India State of Forest Report, FSI, 2017, the forest cover in the state is 1,588 km^2 which is 3.59 percent of the state's geographical area. Geology of the state is characterised by the Siwalik system, the Indo-Gangetic plain and the Aravali system. Physiography is characterised by the structural hills of the Siwaliks, the piedmont plains, central plain and the structural hills in the Aravalis and the shallow sediments (Singh 1971: 88, Duggal 1975: 3-5).

Average annual rainfall in the state varies from more than 100 cm to 30 cm in the extreme western parts of the state. Average annual temperature varies between 24 to 26 °C. Average relative humidity (RH) in the state has been recorded to around 65 which vary from 45 to more than 80 in different seasons of the year. Climate of the state is subtropical continental monsoon type. The state is divided into tropical desert, hot and arid climate, tropical steppe, semi arid hot climate which are characterised by subtropical monsoon, mild and dry winter and hot summer climate (IMD 1989, Singh 1976:44-45). Soils of the state are Sandy and loamy sand (*bagar*), relatively sandy loam, sandy soft loam (*rohi*), coarse loam (*dahar, chaeknote*), light loam (*seoti*), loam (*bhangar and nardak*), silty loam (*khadar*), clayey silt (bet), silt clay (*naili* and *chhachhra*, *dakar*), Siwalik soils (*pahari*), piedmont (*ghar and kandi*), rocky surfaces. The pH value of these soils varies between less than 7.50 (in northeast) to more than 9.77 in the southeastern part of the state (Singh 1976:91, Zaidi 2011:1-74).

ABOUT THE PLANT: LEMONGRASS

Lemongrass belongs to the family of Cymbopogon that has speciated into two species of *Cymbopogon flexuous* Stued Wats. ('East Indian lemongrass') and *Cymbopogon citratus* Stapf. ('West Indian lemongrass'). A third variey, *Cymbopogan pendulus* Nees ex Steud. Wats., has also been adopted for cultivation in India. The present investigation takes into account only *Cymbopogon flexuous* Stued Wats. Lemongrass may adapt to a variety of ecological and geographical conditions, but it is a tropical grass that grows well in warm and humid conditions.

A day time temperature ranging from 25 to 35˚C with no extremely low night temperature is considered to be optimum for maximum oil production. It occurs naturally in India from sea level to 1,200 meters of altitude. High intensity of sun light and rainfall at higher altitudes adversely affects leaf oil content. In both species, oil content decreases during long-dry and sunny spells, which occur more often at higher than lower altitudes. It is a tropical grass and grows well in humid tropical areas with bright sunshine and high humidity with well distributed rainfall. However, it can be cultivated in sub-tropical areas also which do not have frost conditions. It requires a rainfall ranging from 200 to 300 cm and can tolerate short periods of water-logging. Areas, which receive an annual rainfall from 175 to 200 cm are also suitable for cultivating lemongrass. In these areas, if rainfall is well distributed, no irrigation is required. However, when this grass is cultivated in areas where there are long dry spells, it should be irrigated 4 to 5 times or as the need may be.

The lemongrass is adapted to a wide range of soils, but well drained sandy loam and medium loam soils are good for its growth. It thrives well even in light sandy soils provided they are well manure. Although, this grass prefers neutral soils but it can also be cultivated in moderately alkaline soils with pH value up to 8.5. In India the soils of pH value varying from 5.5 to 7.5 are utilized to cultivate this grass, sometime it can be cultivated in soils of higher acidity up to 9.6 on pH scale. Therefore, less fertile areas with adequate irrigation facilities can also be brought under the cultivation of the lemongrass in Haryana (Virmani 1977:6-7). On an average, one hectare of land produces 70 to 80 tons of green leaves and 150 to 200 kilograms of oil (Chandra 2004:175). The percentage yield of oil from fresh herbage varies between 0.2 and 0.5 per cent and decreases with the age of plantation. Some HYVs developed in India i.e., OD-19, OD-408, OD-440, OD-58, CK-25, Pragati, Cauvery and Praman yield larger amount of herbage as well as oil (Tyagi 2003:43-44).

METHODOLOGY OF AGROECOLOGICAL ZONING

Agroecological zoning is method of comparing environmental, pedological and agricultural conditions of the potential crop/plant and the area and demarcate suitable zones. Therefore, a comprehensive study of the agroecological conditions where lemongrass is naturally found or is being cultivated has been done to collect suitable data and information. For the cultivation of this plant in the state of Haryana, a spatial framework has been developed to identify land units with similar agroecological conditions. This framework also has been used to identify areas from which representative agricultural fields and households have been selected for collecting information on inputs, management practices, water use and availability and soil characteristics. This data collected from both primary and secondary sources has led to the evaluation of potential and constraints of different areas in the state of Haryana by employing the concept of geographic equivalence, locales (zones) with similar agroecological characteristics.

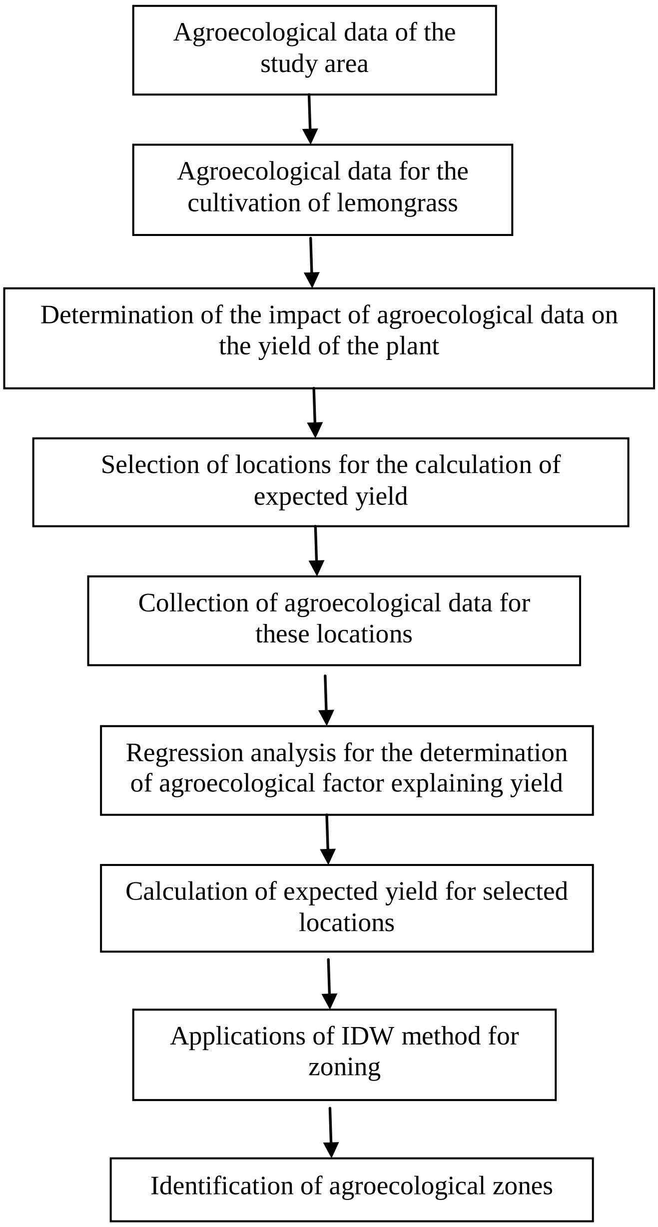

Diagram. 1: Methodological steps of agroecological zoning

The first step in this process has been identification of key climatic and edaphic and agricultural variables which are scientifically proved most important for the cultivation of different crops and plants in India and around the globe. On the basis of these determinants and observed yields of this plant in varying environmental conditions, explanatory functions are derived for calculating yield. These functions have been used to predict yields of this plant for 95 selected sites (villages) from which agroecological data have been collected (Figure1). Information on climatic, edaphic and other agricultural variables which may possibly influence its oil yield is collected. However, a review of expert literature on lemongrass revealed that annual rainfall, relative humidity, annual mean minimum and maximum temperature and annual mean temperature are the main predictors of oil yield of these grasses. These data in the case of lemongrass from parts of India and other places in the world where it is successfully cultivated have been collected.

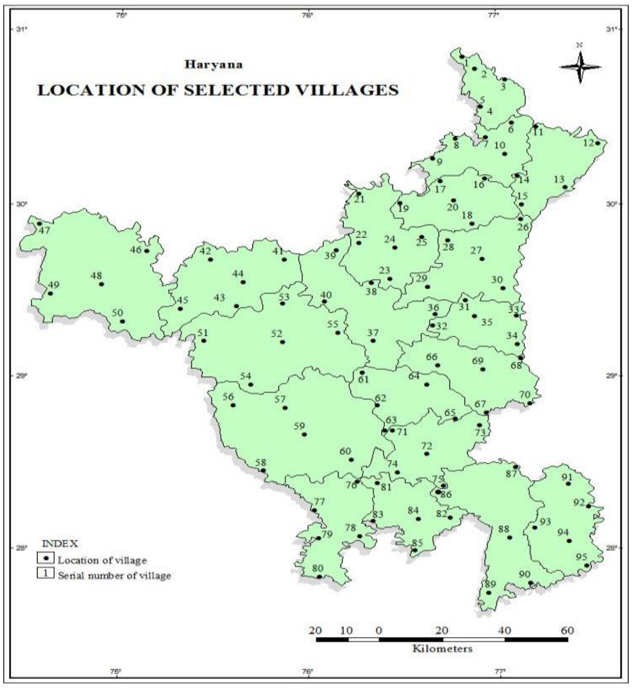

Figure 1: Location of selected villages in Haryana

For the purpose of calculating expected yield in the statistical package IBM SPSS all given curvilinear multivariate functions and also Cobb Douglas and stepwise linear regression have been experimented with. An inspection of the explained variance in the average oil yield of lemongrass has revealed that the stepwise regression analysis explains most of it with a high significance of regression coefficients and an F statistics at a very high level of significance pointing out a very reliable fit of the model:

$$YL = 106.349 + 0.021*RF + 2.238*MN \quad R^2 = 0.774, \text{ Adjusted } R^2 = 0.770, F = 34.079$$

(0.000)   (0.000)   (0.000)   (0.000)[1]

1. Figures in parentheses are significance levels of parameters.

Where, YL is oil yield of lemongrass, RF is annual rainfall and MN is mean annual minimum temperature. An inspection of these values show that only annual rainfall and minimum temperature are retained in the equation whose regression coefficients are very significantly different from zero (0.0) meaning thereby that these regression coefficient may be relied upon for prediction and so is case with the constant (106.349). The Value of R^2 is 0.774 which after adjustment turns out 0.770 signifying that at least 77 per cent variation in the observed yield of lemongrass all around the world is explained by these two predictors. Significance level of F statistics validates the fitted model with a high degree of confidence.

In the second instance, annual mean temperature and annual rainfall plus volume of irrigation water in mm over the geographical area of sample villages are used to predict the oil yield of lemongrass at these 95 sites. The predicted oil yields are taken merely as indicator of suitability and form a reasonable basis of agroecological zoning for this aromatic plant.

In the third instance, the file of predicted lemongrass oil yields has been attached with the location code file of the sample villages in ArcGIS 10.3 environment. Using IDW method of interpolation in the Spatial Analyst kit of the ArcGIS 10.3, surfaces of yield distribution are interpolated. In this method value at an unknown point is calculated as weighted sum of the values of N known points. Inverse distance weighting (IDW) method has advantage over the other methods of interpolation as this method is best suited for randomly distributed point data. In the present analysis a variable search radius of minimum of 10 map units and a minimum of 5 points are used with the calculation of weights of distances by squaring distances in order to minimise bias due to higher values at farther distances. This interpolation has given a number of zones. Therefore, a resampling is carried out by assigning three natural breaks which classified all the interpolated zones into four zones (Figure 2). After resampling into four zones, vectorisation is carried out to draw clear boundaries between different zones.

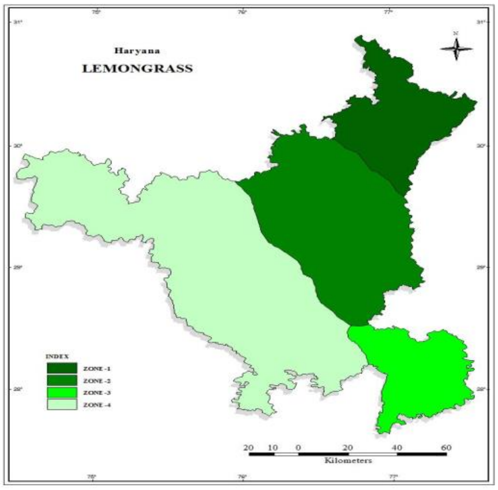

Figure 2: Agroecological zones of lemongrass

On the analysis of the lemongrass oil yields per hectare in each of these four zones in Figure 2, it is found out that the darkest green polygon (zone) represents an area most suitable for the cultivation and commercial profit from this plant, the green zone represents a suitable zone for raising lemongrass with appreciable profits, the area represented in dull or faded green is less suitable for its cultivation as profit earned from the production of this aromatic plant though will be higher from that of conventional cropping but not significantly higher to recommend to allocate a large area under this plant in this zone. The lightest green area represents a zone where cultivation of lemongrass will be a loss incurring enterprise in comparison to conventional farming. Therefore, this zone is designated least or unsuitable for cultivation of lemongrass.

Agroecological zones for lemongrass cultivation

In the Table 1 below is given area and its percentage in the total geographical area of Haryana of each of four agroecological zones as demarcated on the basis predicted level of oil yield of lemongrass at varying levels of suitability (Figure 2).

Table 1: Level of suitability and area of different zones for lemongrass cultivation in Haryana

S.N.	Zone	Level of suitability	Area in km^2	Area in per cent
1.	Zone 1	Most suitable	5,986.87	13.54
2.	Zone 2	Suitable	12,532.42	28.35
3.	Zone 3	Less suitable	4,782.28	10.82
4.	Zone 4	Least or not suitable	20,910.43	47.29

Zone 1

This zone is most suitable for lemongrass cultivation in the state. It is located in northern Haryana. Total area under this zone is 5,986.87 km^2 or 13.54 per cent of total area of the state. It is ideally located below 1,200 metres of altitude, but it receives 700-1000 mm of average annual rainfall which is comparatively lower than the required amount for its commercial cultivation. Average day time temperature has been recorded to vary between 20˚C-30˚C in this zone. The sandy loam soils of this zone are ideal for the cultivation of this grass. The characteristic pH value of soils in this zone is below 7.5. While, the ideal limit ranges between 5.5 and 7.5, though this grass is tolerant to a value up to 9.6 on pH scale. The growing period of 120-210 days in this zone is longest and also favorable for the cultivation of this grass in the state (Sachdev *et al.* 1995).

Zone 2

This zone is just suitable for cultivation of lemongrass in the state. The total area covered by this zone is 12,532.42 km^2 or 28.35 per cent. Its altitude varies between 230-250 metres from west to east. Annual mean minimum and maximum temperature in this zone is recorded 17 and 32° C respectively which are suitable for its cultivation. But, the average annual rainfall is comparatively lower ranging from 500 to 750 mm. This zone is also characterized by a variety of soils including silty loam, loam silty clay and light loam, with their pH value ranging from 7.5 to 8.5 presenting an ideal range for the cultivation of this grass. Thus, the low availability of rainfall makes this zone just suitable for raising lemongrass. However, developed irrigation resources can make up for this deficiency.

Zone 3

This zone is less suitable for lemongrass cultivation in the state compared to the previous two zones. Total area covered by this zone is 4,782.28 km^2 or 10.82 per cent of total area of the state. Average annual rainfall in this zone is around 500 mm. The soils of this area are silty clay, loam, sandy loam, and sandy. These soils are alkaline and their pH value ranges between 7.5 and 8.5, which does not necessitate extra measures for the successful cultivation of this grass. Thus, this zone is less suitable. But, rainfall deficiency by irrigation coupled with labour intensity can make up for poverty of soils as higher yield of this grass in Mewat district exemplifies.

Zone 4

This zone is not suitable for lemongrass cultivation in the state. It covers a large area of 20, 910.43 km^2 or 47.29 per cent of total area of the state. This region receives less than 50 cm rainfall which decreases towards west and south. There are varied soils in this zone which are mostly sandy with an average pH value of more than 8.5. Thus, lack of water and suitable soils in this zone are major constraints in raising this grass on large scale.

CONLUSION

Delineation of an area into agroecological regions is necessary for continued supply of food, fiber, fuel, fodder and herbal products, which due to reckless exploitation from the wilds and also other competing land uses are threatened and endangered to extinction. Also to meet other demands of farming communities to increase their declining incomes and for continued availability of natural aroma and other herbal products in national and international market, rationalisation and spatiation of cropping systems is urgently required. By spatiation of cropping systems is meant adoption of sustainable cropping systems (a mix of crops and MAPs) at regional and local scales such that it is suited to environmental conditions of a region and is efficient in utilizing naturally available nutrients and moisture with little or no human subsidy. It should also be capable of enhancing employment and incomes of rural households. In the present study those zones have found where lemongrass cultivation may be suitably adopted by the farmers especially in those areas where traditional crops have become uneconomic to cultivate. An analysis of the agroecological zones of lemongrass reveals that this plant can be suitably introduced in northern and north central part of the state. South eastern part of the state may also be utilized to raise this plant with the supply of more water and introducing it along canals. Northern part of the state where rainfall ranges from 70 to 100 cm, the cultivation of the lemongrass may be adopted with help of irrigation. In western part very low availability of rainfall and increasing pH of the soil do not support its cultivation. Actual cultivation of this plant in the state will reveal its suitability and present work is just an exploratory research.

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