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ORIGINAL ARTICLE

Crop Combination Regions in the Environs of the Malaprabha River Basin, Karnataka State, India

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ABSTRACT

The present study is an attempt to identify agricultural crop combination regions in the Malaprabha River Basin, Karnataka State, India, for better land use planning. The Malaprabha River Basin of Karnataka State is approximately triangular and located in the extreme western part of the Krishna basin. Topographically, the Malaprabha river basin presents two important divisions, viz., the Western Ghats and the typical eastern part of the Deccan/Karnataka plateau, with distinct characteristics. The entire river basin experiences a semi-arid type of climate, spread in the hilly, Northern dry, and Northern Transition zones of the Agro-Climatic Zones of Karnataka State. The annual normal rainfall of the Malaprabha basin area is over 759 mm spread over 50 days, which receives monsoon rainfall as much as our nation with slight variations. The dominance of rural populations makes the regional economy mainly agrarian. The basin's 68.37% of the workforce (61.75% of males and 79.55% of females), however, is still dependent on agriculture and its allied activities for their livelihood. The economic development and prosperity of the masses depend mainly on agriculture. Rafiullah (1965) modified Weaver's method and introduced a new method known as the "Maximum Positive Deviation Method" to compute crop combination regions for the taluka level of the Malaprabha river basin area in Karnataka state because of its precision.

Keywords: *Agriculture, Landuse, Agro-Climatic Zones, Agricultural region, Crop Combination.*

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INTRODUCTION

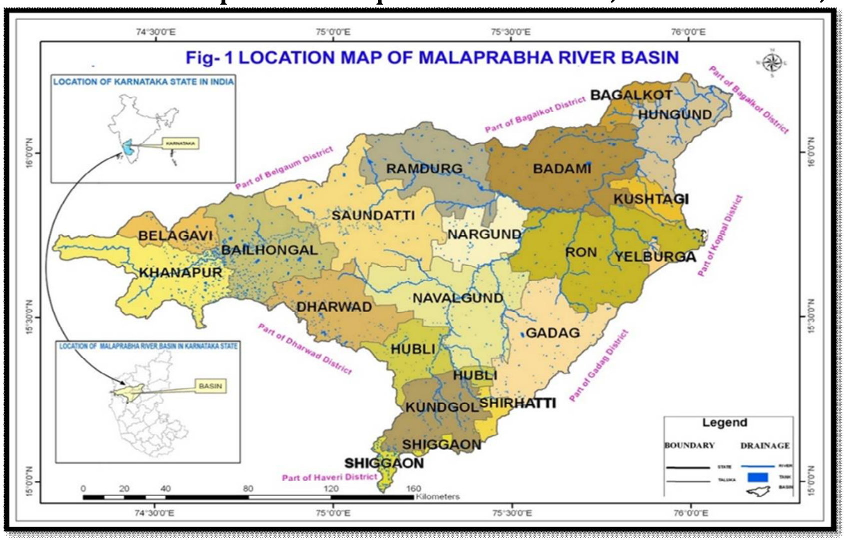
Crops are generally grown in combinations [9]. The first attempt at delineating agricultural regions in the Middle West United States was made by Weaver in 1954. The study of crop combinations in any region has gained importance in geographical studies. It gives us the relative position of crops on a regional scale. Farmers grow crops in varied physical and cultural conditions. The pattern of crop combinations gives the spatial distribution of certain crops or combinations, resulting in the emergence of crop regions. Such analysis would ultimately minimize the chances of oversimplified generalization [1]. The Crop combination analysis in agricultural geography is fruitful in many ways. First, it provides adequate concern for a significant or individual crop. Secondly, combination analysis is an integrative reality that demands definition and distributional analysis, and finally, crop combination regions are essential for the construction of a more complex structure of a vivid agricultural region [10]. The study of crop combination thus forms an integral part of agricultural geography, and such study is greatly helpful for regional agricultural planning. The first attempt at delineating agricultural regions was made by Weaver in 1954. He studied crop combinations for Middle Eastern countries. Later, many more methods were introduced. Coppock [5] also modified a version of Weaver's method, wherein he considered rank in recognizing the leading crops.

The study of crop combination has great importance in the study of land use, and its regions constitute an important aspect of Agricultural Geography as they provide a good basis for agricultural regionalization and all the countries, land is used for agricultural purposes to a large extent, and the description and analysis of various problems relating to agriculture have contributed a great deal to the contents of the economic and regional geography. The study of crops on a regional scale must take combinational analysis and the relative position of crops into consideration. A general understanding of the combination of crops and relative importance of each in an area would be helpful in interpreting some aspect of the social and economic geography of the region, and this will also reflect the variable position of the individual crops [4-9]. The present study attempts to study agricultural regionalization at the taluka level of the Malaprabha river basin area in Karnataka state.

STUDY AREA

The Malaprabha River Basin of Karnataka State is approximately triangular and located in the extreme western part of the Krishna basin. It lies between 15^{0} 05^{I} 02^{II} to 16^{0} 20^{I} 19^{II} N. latitudes and 74^{0} 05^{I} 43^{II} to 76^{0} 05^{I} 33^{II} E. longitudes, covering an area of 11549 sq. km, out of which 3880 sq. km are in Belgaum (33.59%), 1950 sq. km in Bagalakot (16.89%), 2739 sq. km in Dharwad (23.72%), 2657 sq. km in Gadag, 220 sq. km in Koppal, and 103 sq. km (Fig.1). Topographically, the Malaprabha river basin presents two important divisions, viz., the Western Ghats and the typical eastern part of the Deccan/Karnataka plateau, with distinct characteristics. The plateau has two natural sub-divisions, the Semi-Malnad and the Northern Maidan, which include the northern upland, or the Deccan trap, of the state. An exhumed structure with superimposed drainage is also responsible for the sharp relief in the Kaladgi sandstones, in which Ghataprabha forms a waterfall near Gokak and the Malaprabha forms a gorge near Saundatti [7]. The river Malaprabha is the most important right-bank tributary of the river Krishna. The Benni Hall, Hire Hall, and others are the principal tributaries of the Malaprabha River.

Figure-1. Location Map of the Malaprabha River Basin, Karnataka State, India



The entire river basin experiences a semi-arid type of climate, spread in the hilly, Northern dry, and Northern Transition zones of the agro-Climatic Zones of Karnataka State, and it is very warm during the summer, especially in April and May, with temperatures ranging between 35^{0} and 400 °C in the eastern part of the river basin. The annual normal rainfall of the Malaprabha basin area is over 759 mm spread over 50 days, which receives monsoon rainfall as much as our nation with slight variations. Deep black cotton soils are ubiquitous in the basin area. Jowar, besides other drought-resistant inferior small millet crops, is traditionally the predominant crop. Geographically, deep black cotton soils, Unpredictable monsoonal rainfall, droughts, and famines are part of the lives of people in the study region. The present study is a natural region that occupies 6.02% of the Karnataka state. As per the 2011 census, the population of the Malaprabha River Basin is 3.38 million (5.53% of the state's total population), of which 77.66% are rural and 22.34% are urban. The dominance of rural populations makes the regional economy mainly agrarian. The basin's 68.37% of the workforce (61.75% of males and 79.55% of females), however, is still dependent on agriculture and its allied activities for their livelihood. The economic development and prosperity of the masses depend mainly on agriculture.

OBJECTIVES

The present paper is an attempt to study the agricultural regionalization at the taluka level of the Malaprabha river basin, Karnataka State, India. In this context, the study has been undertaken with the following specific objectives:

- To identify the crop combination regions in the talukas of the river basin and

- To suggest appropriate strategies in the light of prevailing agricultural government policies and programmes for the development and prosperity of the rural masses in the environs of the Malaprabha river basin

MATERIAL AND METHODS

The present study is mainly based on secondary sources of data. Agricultural data such as area under crops of all the talukas of the basin area from 1973-74 to 2013-14 for the present analysis has been obtained mainly from The Directorate, Department of Economic and Statistics, Bangalore, District Statistical Offices of Belgaum, Dharwad, Gadag, and Bagalkot districts, and the District Census of Belgaum, Dharwad, Gadag, and Bagalkot districts from 1971 to the 2011 Census from the Directorate of Census Operations, Bangalore, Karnataka State; besides this, data were also collected from various government offices and websites.

Presently, the taluka is considered the smallest unit of analysis. To achieve the objectives mentioned above, relevant statistical tools like percentages, averages, variations, and others, as well as methods of quantitative analysis like, Rafiullah (1965) modified Weaver's method and introduced a new method known as the "Maximum Positive Deviation Method" to compute crop combination regions for the taluka level of the Malaprabha river basin area have been employed. To describe the spatial pattern of crop combination regions in the Malaprabha river basin, all the talukas are grouped into different categories to show the existing combinations of crops in the basin area. At last, the results were presented with suitable diagrams and figures.

RESULTS AND DISCUSSION

The study of crop combinations in the Malaprabha river basin is fruitful in many ways. First, it provides an adequate understanding of an individual crop. Secondly, combination is an integrative reality, and finally, crop combination regions are essential for the construction of a more complex structure of vivid agricultural regions [10]. Individual crops may be studied in Geography for their own sake. But all crops studied individually cannot depict the truth of the agricultural complex of the region. The real dominance of certain crops in their varied combinations can be best studied by attempting some kind of synthesis. Thus, the study of crop combination analysis minimizes the chance of oversimplified generalization. Generalization needs a compact system of agriculture. The planning and development of agriculture are aimed at the upliftment of the rural agrarian poor and, consequently, the development of the nation in general and the present study area in particular. Several quantitative and qualitative methods have been used for computing crop combination regions. Qualitative methods are more precise, accurate, and scientific than qualitative methods.

J. C. Weaver's Method:

In his 1954 study on the crop combination regions in the Middle West, USA, Weaver used the minimum deviation method, which is essentially statistical and takes into consideration percentages of crop acreage to total cropped area. In his work, Weaver calculated the deviation of the real percentage of crops (occupying over 1% of the cropped area) for all the possible combinations in the component area units against a theoretical standard. The theoretical curve for the standard measurement was employed as follows:

Mono-culture = 100% of the total harvested crop land in one crop.
2 Crop combination = 50% in each of the two crops
3 Crop combination = 33.3% in each of the three crops
4 Crop combination = 25% in each of the four crops
5 Crop combination = 20% in each of the five crops

For the determination of the minimum deviation for each of the component areal unit the standard deviation method is used, which is as follows.

$$\delta = \sqrt{\frac{\sum d2}{n}}$$

However, Weaver has pointed out the relative rank of the amount of deviation among the several possible combinations as was desired by him and not the actual magnitude of the deviation, the square root was extracted in accordance with the standard deviation formula. The specially used variant procedure can, therefore, be expressed as follows,

$$\delta = \frac{\sum d2}{n}$$

Where, $\bar{\delta}$ = Value of crop combination, **d =** the difference between the actual crop percentage in each area unit and the appropriate percentage in the theoretical curve and **n** = is the number of crops in each combinations.

Doi's method of crop combination: (Minimum deviation method)

This was an improvement upon Weaver's method, and it has been put forward by Doi Kikukazi (1959). This new method substitutes d2 / **n** of Weaver's by the sum of the squared difference from the theoretical value. Thus, the combination having the smallest sum of deviation (d2) will be the best-suited combination forwarded by the important crops. The formula is as follows:

Monoculture	$= (100-42)^2 = 3364$
2 crop combination	$= (50-42)^2 + (50-18)^2 = 1088$
3 crop combination	$= (33.33-42)^2 + (33.33-18)^2 + (33.33-14)^2 = 682$
4 crop combination	$= (25-42)^2 + (25-18)^2 + (25-14)^2 + (25-9)^2 = 715$
5 crop combination	$= (20-42)^2 + (20-18)^2 + (20-14)^2 + (20-9)^2 + (20-8)^2 = 789$

Since the variance of 3 crop combination (682) is the smallest, the unit is designated with 3 crop combination.

Athawale A. G. Method: (Lower limit method)

Athawale A. G. [2] has evolved three new methods for crop combination analysis that are less time-consuming and sometimes yield a smaller number of crops. These three methods are:

1. Method of Differences.
2. Method of Summation and
3. Lower Limit Method.

These methods devised by him have been fully described and tried in Andhra Pradesh at district level to derive the crop combination in his paper. After describing all three methods in detail, he himself opines that the third method is the best and is being taken into consideration in the paper. In this method, Athawale has attempted to associate the value of N (the number of crops to be included in the combination) with the crop combination. To attain the lower limit in terms of acreage of crops in hectares, the formula given below

Formula:

$$A = \frac{G}{3N}$$

Whereas; **A** – the lower limit in terms of acreage, **G** – Gross cropped area: and **N** – Number of crops having acreage more than or equal to G/100

According to this formula, all crops having an acreage greater than 'A' will find a place in the crop combination. To illustrate this technique, Athawale has given an example, which is as follows:

Let **G**=1260 and the crop acreage be 800, 200, 160, 50, 25, 10, 10 and 5.

Then;

$$Formula = \frac{G}{100}$$

$$= 1260/100$$
$$= 12.60$$

Hence **N**=5 (since only 5 crops have acreage more than 12.60) and lower limit

$$A = \frac{G}{3N}$$
$$= 1260/3X5$$
$$= 84$$

There are 3 crops above 84, and hence the combination would be triglycerides-culture, i.e. 3 crop combinations.

Rafiullah's crop combination method: (Maximum Positive Deviation Method)

Even after the modification Weaver's method, however in cases of one or two functions are predominantly significant and all of one or two functions are equally insignificant, gives undue importance to the functions of very low significance. In many empirical problems, therefore, Weaver's method does not give intuitively correct results. The basic reason of this fallacy in Weaver's method as pointed out by S.M. Rafiullah [11] is that:

a. It ignores the signs of the deviations, and
b. For a higher number of crops or functions the theoretical percentages go down and so the deviations caused by least values are under-estimated.

The **Formula** introduced by him is as follows:

$$d = \frac{ED2p - D2n}{N2}$$

Where: D = Deviation, DP = positive differences, DN = Negative differences from the modal value and N = Number of crops

The under-root sign may be ignored to save laborious calculations and this formula may be used in the following form:

$$d = \frac{ED2p - D2n}{N2}$$

Unlike weaver the difference of actual value is calculated from the middle value of the theoretical standard, and the maximum positive deviation gives the critical combinations. To illustrate this technique Rafiullah has given an example, which is as follows. Suppose the percentage area under various crops is as follows.

Rice is 54 percent, wheat is 23 percent, barley is 9 percent, and sugarcane is 5 percent. Then the maximum positive deviation of variance will be,

Mono crop	$= (54–50)^2 / (1)^2$
	$= (4)^2$
	= 16
2 crop combination	$= (54– 25)^2 – (23–25)^2/ (2)^2$
	= 209.25
3 crop combination	$= (54–16.70)^2–(23–16.70)^2–(9–16.70)^2/ (3)^2$
	=140.18
4 crop combination	$= (54-12.5)^2-(23-12.50)^2–(9–12.5)^2–(9–12.5)^2/(3)^2$
	= 110.20

The maximum difference of variance is 209.25 for the two-crop combination, which is the best-suited combination of Rice and Wheat. This sort of exercise of the maximum positive deviation method by Majid Hussain in Uttar Pradesh, delineating crop combination regions up to ten crops and about six crop combinations, may well be recognised.

The overall outcome of Weaver's method may be used as a guide for a statistical approach to analyse spatial variations in agriculture. This has cleared the way for new methods and techniques to be applied for delineating agricultural regions, but unfortunately, this method, with all its modified versions, suffered from several weaknesses as compared to other methods. In this method, the differences in actual percentage values are calculated from the median theoretical standard value, which is an advantage over Weaver's method as it reduces the number of crops in the combination. Weaver's and Doi's methods and the Athawale method have particularly failed to delineate a precise combination and include all crops occupying as much as one percent of the total cropped area. But the application of Rafiullah's method gives such combinations as are true representative of primary crops. The maximum positive deviation method devised by Rafiullah gets preference over Weaver's, Doi's, and Athawale's methods, as this method reduces the number of crop combinations. Thus, it simplifies the crop association, which can be helpful in the delineation of agricultural regions in the chosen area. Thus, the method would give the desired critical combination.

The statistical technique adopted by Rafiullah is more accurate and rational, and therefore it is quite popular for delineating crop combinations in regions. Keeping in mind the merits of Rafiullah's method, it is used in the present study for computing crop combination regions in the Malaprabha river basin. According to this method, the percentage of area for all crops was arranged in descending order. The crops having an area less than five percent were omitted from the calculation, and the maximum positive deviation was calculated. For monoculture, the median value was considered at 50 percent; for two crop combinations, it is 25 percent; for three crop combinations, the value is 16.7 percent; for four, it is 12.5 percent; and for five crops, it is 10 percent, and so on. In the present study area, 15 crops were used for the computation of the crop combination region. The obtained results of crop combination are shown in Tables 1 and 2, and Fig. 2. In the study region, there has been a remarkable change in the crop combination over a period of forty years in the river basin. Three different types of crop combination regions have been identified in the Malaprabha river basin. The crop combination regions varied from two to six during 1973–74, from two to seven during 1993–94, and from two to nine during 2013–14. The details are as follows:

Two Crop Combinations: During 1973–74, the two-crop association of Paddy and Fodder was confined only to the Khanapur and Jowar talukas, and Cotton was observed only in the Hunagund talukas of the river basin. During 1993–94, it was observed in the same talukas with a change of crops, i.e., Paddy and Sugarcane are confined only to the Khanapur taluka, and Sunflower and Jowar are observed only in the Hunagund taluka. Whereas in 2013-14, the only Khanapur taluka fell under this category of two crop combinations, with the major constituent crops like Paddy and Sugarcane in the river basin (Table 1). Khanapur taluka, where soils vary from rich paddy soils to light red. Rainfall is reasonably high, i.e., 1500 mm to 2000 mm, and the moisture deficit is from December to May. Rice is the main subsistence crop raised without irrigation along the foothills and valley basins. Fodder and other minor millets are grown on poor soils in the eastern part of the taluka, where fields cannot be re-sown after the summer due to inadequate moisture during the winter. Due to the vast area and favourable conditions for cultivation of Jowar and cotton, these are the responsible factors in Hunagund taluka.

Three Crop Combinations: The three-crop combination included five talukas in 1973–74, where moderate rainfall, a semi-humid climate, and rich black cotton soil resulted in the cultivation of important crops like Jowar, groundnut, and Bajra. The black cotton soil area is confined to the talukas of the central, eastern, and western parts of the basin. They are Badami (Gn, J, B), Naragund (W, J, C), Ron (C, J, Gn), Hubli (J, C, W), and Navalgund (W, C, J) talukas. The different combinations are due to variations in the soil cover from black to red sand and the distribution of rainfall in the north-eastern part of the basin. During 1993–94, it was observed in only Badami (J, B, and Gn) and Kundagol (Sp, C, and Gn) talukas. In 2013–14, this category was confined to only the Naragund (M, W, and Blgm) taluka of the river basin.

Four Crop Combinations: This combination included the areas of Bailhongal, Gadag, and Kundagol talukas in 1973–74. These talukas constitute a contiguous block and an area situated in the north-eastern part of the region, where the soil is mainly black and sandy, and the annual rainfall is over 800 mm. In Gadag (C, J, Gn, W) and Kundagol (C, J, Gn, W), cotton ranks first, and Jowar ranks first in Bailhongal (J, Gn, Hrgm, C) taluka of the basin. Combinations are noticed among cotton, Jowar, groundnut, wheat, and Horse gram in all three talukas. In 1993–94, four crop combinations were observed, and they lie in the areas of Bailhongal (C, J, S, and Gn) and Ramadurga (J, Snfl, Gn, and M) talukas. Cotton, Jowar, sugarcane, sunflower, groundnut, and Maize were the major constituent crops. Whereas in 2013-14, there were four talukas that fell under this category, namely Bailhongal (Sybn, J, C, S), Ramadurga (J, M, S, Grgm), Hunagund (Blgm, J, Snfl, Gn), and Kundagol (C, Gn, Sp, J), with major crops like Soybean, Jowar, Bengal gram, and cotton.

Table-1 Classifications of Talukas on the bases of Crop Combination Regions in Malaprabha River Basin Area, Karnataka during 1973-74 to 2013-14 (As per Rafiullah Method)

Sl. No.	Talukas	1973-74		1993-94		2013-14	
		No of Crop Combinations	Name of the Crops	No of Crop Combinations	Name of the Talukas	No of Crop Combinations	Name of the Talukas
1	Khanapur	2	P, F	2	P, S	2	P, S
2	Bailhongal	4	J, Gn, Hrgm, C	4	C, J, S, Gn	4	Sybn, J, C, S
3	Saundatti	5	J, C, W, Gn, B	5	J, C, W, M, Gn	6	J, M, Blgm, S, W, C
4	Ramadurga	5	J, Gn, B, W, C	4	J, Snfl, Gn, M	4	J, M, S, Grgm
5	Badami	3	Gn, J, B	3	J, B, Gn	5	J, M, B, Snfl, Gn
6	Hunagund	2	J, C	2	Snfl, J	4	Blgm, J, Snfl, Gn
7	Naragund	3	W, J, C	5	M, J, C, W, Snfl	3	M, W, Blgm
8	Ron	3	C, J, Gn	5	J, Snfl, Gn, W, Blgm	5	Blgm, Grgm, J, Snfl, V
9	Gadag	4	C, J, Gn, W	6	J, Gn, Snfl, C, Blgm, W	7	Blgm, C, J, Grgm, Gn, V, W
10	Dharwad	5	J, W, Rg, F, Gn	7	J, C, P, Gn, W, V, Grgm	9	Blgm, P, J, M, Gn, Sybn, C, Grgm, Sp
11	Hubli	3	J, C, W	6	C, Sp, J, Gn, W, V	5	C, Gn, Sp, V, J
12	Navalgund	3	W, C, J	6	W, C, J, Blgm, Sp, M	5	C, Blgm, M, W, V
13	Kundagol	4	C, J, Gn, W	3	Sp, C, Gn	4	C, Gn, Sp, J
	MRB	4	J, C, Gn, W	5	J, C, Snfl, Gn, W	8	Blgm, J, C, M, Grgm, Gn, W, Snfl

Source: Classification derived after ranking of the talukas

B; Bajra, Blgm; Bengal gram, C; Cotton, F; Fodder, Gn; Groundnut, Grgm; Green gram, Hrgm; Horse gram, J; Jowar, M; Maize, P; Paddy, Rg; Ragi, S; Sugarcane, Snfl; Sunflower, Sp; Spices, Sybn; Soybean, V; Vegetable, W; Wheat

Figure-2. Crop Combination Regions in Malaprabha River Basin Area, Karnataka during 1973-74 to 2013-14 (As per Rafiullah Method)

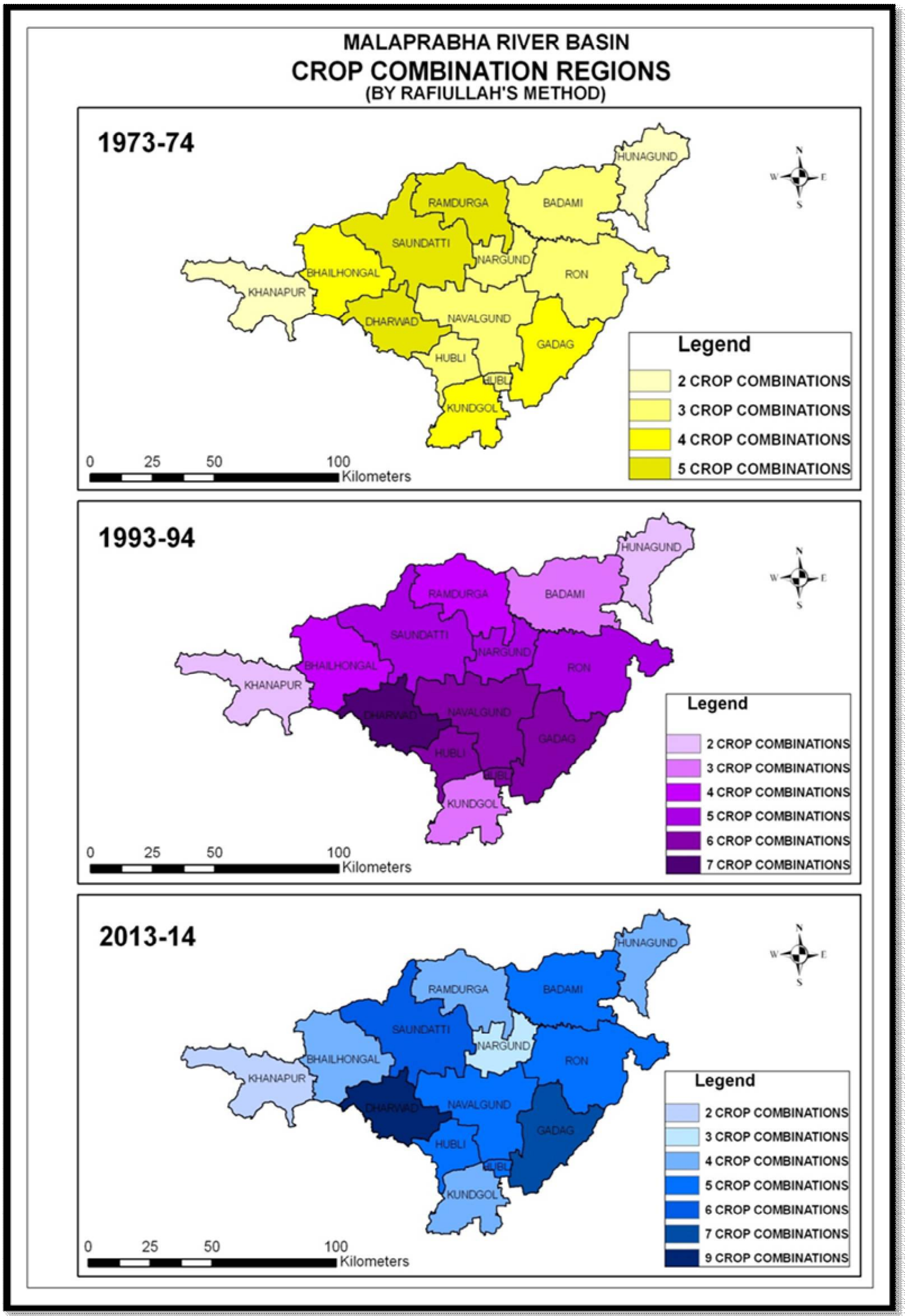


Table-2 Classifications of Talukas on the bases of Crop Combination Regions in Malaprabha River Basin Area, Karnataka during 1973-74 to 2013-14 (As per Rafiullah Method)

1973-74			1993-94			2013-14		
No of Crop Combinations	No of Talukas	Name of the Talukas	No of Crop Combinations	No of Talukas	Name of the Talukas	No of Crop Combinations	No of Talukas	Name of the Talukas
2-Crop Combinations	2	**2a.** Khanapur **2b.** Hunagund	2- Crop Combinations	2	**2a.** Khanapur **2b.** Hunagund	2- Crop Combinations	1	Khanapur
3- Crop Combinations	5	**3a.** Badami **3b.** Naragund **3c.** Ron **3d.** Hubli **3e.**Navalagund	3- Crop Combinations	2	**3a.** Badami **3b.** Kundagol	3- Crop Combinations	1	Naragund
4- Crop Combinations	3	**4a.** Bailhongal **4b.** Gadag **4b.** Kundagol	4- Crop Combinations	2	**4a.**Bailhongal **4b.**Ramdurga	4- Crop Combinations	4	**4a.** Bailhongal **4b.** Ramdurga **4c.** Hunagund **4d.** Kundagol
5- Crop Combinations	3	**5a.** Saundatti **5b.** Ramdurga **5c.** Dharwad	5- Crop Combinations	3	**5a.** Saundatti **5b.** Naragund **5c.**Ron	5- Crop Combinations	4	**5a.** Badami **5b.** Ron **5c.** Hubli **5d.** Navalgund
--	--	--	6- Crop Combinations	3	**6a.** Gadag **6b.** Hubli 6C.NAVALAGUND	6- Crop Combinations	1	Saundatti
--	--	--	7- Crop Combinations	1	Dharwad	7- Crop Combinations	1	Gadag
--	--	--	--	--	--	9- Crop Combinations	1	Dharwad
	13			**13**			**13**	

Source: Classification derived after ranking of the talukas

Five Crop Combinations: This combination is found in three talukas in 1973–74, which contains black and brown soils. They are Saundatti (J, C, W, Gn, B), Ramadurga (J, Gn, B, W, C), and Dharwad (J, W, Rg, F, Gn) talukas of the basin. The major crops, Jowar, cotton, oilseeds, wheat, and pulses, are in the combination. Much of the diversification in the combination and distributional pattern is due to variation in soil cover, climate, and the attitude of farmers towards cultivating subsistence crops. During 1993–94, only Saundatti (J, C, W, M, Gn), Naragund (M, J, C, W, Snfl), and Ron (J, Snfl, Gn, W, Blgm) talukas had five crop combinations, whereas in 2013–14, five crop combination regions were found in four talukas, namely Badami (J, M, B, Snfl, Gn), Ron (Blgm, Grgm, J, Snfl, V), Hubli (C, Gn, Sp, V, J), and Navalgund (C, Blgm, M, W, V) of the river basin.

Six Crop Combinations: There was not a single taluka falling under this category during 1973–74, but in 1993–94, this combination included three talukas, namely Gadag (J, Gn, Snfl, C, Blgm, W), Hubli (C, Sp, J, Gn, W, V), and Navalgund (W, C, J, Blgm, Sp, M) of the river basin. The total number of crops that invariably enter the combination is nine. Two out of the three talukas (Hubli and Navalgund) form almost a compact block. The only difference in the combination of crops in the two talukas is that in Hubli, Groundnut enters the combination, and Bengal gram and Maize in Navalgund. The soils of these talukas are black and red and are provided by irrigation. In 2013–14, only Saundatti (J, M, Blgm, S, W, and C) taluka of the study area experienced six crop combination regions.

Seven Crop Combinations: This combination was not noticed in any one of the talukas of the river basin during 1973–74, while only Dharwad was the taluka where this combination was observed with seven crops in 1993–94. The Malnad type of climate with a good amount of rainfall (800–900 mm) has induced the cultivation of Paddy and other main food crops in the taluka. In Dharwad taluka, the seven combinations (J, C, P, Gn, W, V, and Grgm) with Green gram, the major pulse crop, enter the taluka. It is because the brown soil, which is suitable for pulses, is distributed in what is called the transition belt, comprising the eastern part of Dharwad. The soil is not as porous as the red and sandy ones and has some retentive power. The diversity in the combinations formed is increased owing to the variations in rainfall from 800-900 mm, the variation in soil from brown to paddy soils, and the interest of farmers in rotating the crops. In 2013-14, only Gadag (Blgm, C, J, Grgm, Gn, V, and W) taluka of the study area experienced seven crop combination regions.

Nine Crop Combinations: Nine crop combination regions were not found in the river basin during 1973–74 and 1993–94, while in 2013–14, only Dharwad (Blgm, P, J, M, Gn, Sybn, C, Grgm, and Sp) taluka of the river basin recognized them as nine crop combination regions. This large variation of crops found in this taluka is mainly due to variations in the amount of rainfall, ragged topography, and other factors.

CONCLUSIONS

Crops are generally grown in combinations (Weaver, 1954). The study of crop combinations in any region has gained importance in geographical studies. It gives us the relative position of crops on a regional scale. In the study region, there has been a remarkable change in the crop combination over a period of forty years in the river basin, as per Rafiullah's "Maximum Positive Deviation Method" (1965). Farmers grow crops in varied physical and cultural conditions. The pattern of crop combinations gives the spatial distribution of certain crops or combinations, resulting in the emergence of crop regions. Such analysis would ultimately minimize the chances of oversimplified generalization. In the present inquiry, three different types of crop combination regions have been identified in the Malaprabha river basin. The crop combination regions varied from two to six in 1973–74, from two to seven in 1993–94, and from two to nine in 2013–14. These changes are mainly due to the varied physical, socio-economic, and cultural conditions prevailing in the river basin. The river basin has natural regions with different agricultural terrains. Obviously, the impact of varied conditions for agricultural development in the Malaprabha river basin on a balanced path needs a 'Citation of POWER' in terms of management, investment, and policy.

- **P**ossible extent by engaging the farmers in Participatory Irrigation Management [PIM] through the establishment of Water User Associations for the development of an adequate delivery system of irrigation water up to the farmer's field with the objective of enhancing water use efficiency, production, and productivity of crops per unit of land and water for improving the socio-economic conditions of the farmers in the river basin.
- **O**ptimal use of all available physical resources, like relief, climate, soils, and water, and non-physical resources, mainly human resources and potentialities, with minimal effect on the environs and to sustain the bright and better future of the river basin.
- **W**ater is the real elixir of life; irrigation is the font of civilization, thus its utilization for the possibility of an increase in productivity (yield per hectare) and income per drop of water through the combination of water, landuse, cropping pattern, and agronomic practices, including soil health, in the river basin. Combination and Diversification of cropping patterns will be encouraged in the river basin. While this will not be possible through direct enforcement, apt incentives or disincentives can be adopted to achieve desired results like enhanced land use efficiency, irrigation and crop intensity, re-usage of degraded land, etc.
- **E**nrichment of new innovative technological advancement strategies in all levels of agricultural practices, like Farm mechanization, including irrigation, tractors, fertilizer, pesticides, and seeds, the Israel method, and rainwater harvesting systems for water and soil conservation measures, are essential and are taken up as a top priority in the irrigated land.
- **R**educe the distance between labs to Land' in the transfer of technology, and there is a need to revive our traditional knowledge and incorporate it in and around the dam sites. The sight of water itself is a great healer, and it also induces tranquilly. Eco-tourism may be encouraged in irrigation projects. These settings not only induce an awareness of respect for Mother Nature' but also generate revenue. Finally, adequate agro-based and agriculturally associated industries, infrastructural accessibility, and services like good transport and marketplaces, timely credit facilities, and food processing units may be created for the overall development of the farming community.

For prosperous agriculture, we must implement the above-mentioned measures in a positive manner, which ultimately results in the narrowing of the gap between irrigation potential created and potential utilized and enhances water use efficiency for sustainable agricultural development in the Malaprabha river basin.

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