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Analytical Hierarchy Process Based Multi-Criteria Analysis And Influence Technique For Agricultural Development Of Micro-Watersheds In Upper Mula River Basin In Maharashtra (India)

Ravindra D.Gaikwad[1], Vijay S. Bhagat[2] Sanjay B. Navale[3], Pandharinath T. Karande[4]
[1]Head and Assistant Professor S.N.Arts, D.J.Malpani Commerce and B.N.Sarda Science college Sangamner, Department of Geograpy, Affiliated to SavitribaiPhule Pune University, Pune, India.422605
[2]Head and Professor, Post-graduate Teaching and Research Center in Geography, Agasti Arts, Commerce and Dadasaheb Rupwate Science College, Affiliated to Savitribai Phule Pune University, Pune, India.422601
[3]Assistant Professor, Adv. M. N. Deshmukh Arts, Commerce and Science College Rajur, Department of Geograpy, Affiliated to SavitribaiPhule Pune University, Pune, India. 422601
Email- georavindra@gmail.com

Abstract:

Agricultural development is unique sign for development of agricultural base country. Multi-criteria, Analytical Hierarchy Process (AHP) Based Multi-Criteria Analysis and Influence Technique is suitable for Agricultural Development (AD). Six criterions (Crops) sugarcane, vegetables, pulses, fruits, rice and grains were selected for development indicators of Mula river basin in Ahmednagar district, Maharashtra (India). Expert opinions for ranking the criterion selected for influence. Sugarcane, vegetables and fruits show higher influences on development of watershed arrangement in the study area. Further, crops grains and pluses were show significant influence in kharip season. Using AHP techniques for influences were calculated based on weights estimated. Normalized and distribution of specific crops using the values of influences within the sub-watersheds. Agriculture developments influence are classified into very low (< Mean-1STD), low (Mean-1STD to Mean), moderate (Mean to Mean + 1STD), high (Mean + 1STD to Mean + 2STD), and very high (>Mean + 2STD) and agricultural development are classified into high (7.86%), moderate (15%) and low (77.14%) categories. The methodology is the effective tool for agricultural development of micro-watersheds.

Keywords: AHP; Ranking; Multi-criteria; Influence; Weights.

Introduction

Agricultural development is significantly representing overall development of the rural regions (Tschirley, 1998; Winnegge, 2005). After independence, Indian government focused on AD through upgrading the irrigation facilities (Johnson *et al.*, 2013), seeds (Tschirley, 1998; Wani *et al.*, 2008; Smith *et al.*, 2008), fertilizers (Wani *et al.*, 2008), technology (Bhan *et al.*, 1996; Peterman *et al.*, 2011), financial support (Pascual-Ferrer *et al.*, 2013; Zolekar and Bhagat, 2015), education and training (Montz, 2008; Vu *et al.*, 2014), etc. Organizations like National Bank for Agriculture and Rural Development (NBARD), Agricultural Finance Corporation (AFC), World Bank, Nationalized banks, etc. have provided financial assistance to farmers for the development of irrigation facilities. However, the expansion of irrigation has exploited the groundwater and water scarcity appeared in the summer season especially in drought regions (Kaushal and Belt, 2012). The irrigated agriculture and orchards began run out of water in these regions. Therefore, WMPs were suggested and undertaken by various governmental agencies, NGOs and local authorities in India for conservation of natural resources including water, soil, vegetation, etc. The main focus of implementing the WMPs was AD (Yongsheng, 2004). Therefore, the assessment of AD is important to understand the success of WMPs.

The study area shows variation in land, soil and rainfall characteristics, availability of water resources, quality of human resources and therefore nature of agriculture and cropping pattern in the region. The slope decreases towards the East from western hilly region. Higher rainfall, steep slopes and dense forests are observed in western hilly region. Paddy and *Nagali* are important crops in this area. Further, Sugarcane, Vegetables and Fruits are observed in the eastern part with the gentle slopes. Gumma *et al.* (2016) have used weighted integration of multiple thematic layers, Gassman *et al.* (2007), Daloglu *et al.* (2014) have used soil and water assessment tool, Panhalkar (2011) has used intersect overlay technique with GIS environment, Daloglu *et al.* (2014) have used Agent-Based Models (ABM) with combination of SWAT, Bouma *et al.* (2011) have used water balance of irrigation systems for AD. Further, AHP based multi-criteria analysis and influence technique is useful tool for quick assessment of AD in micro-watersheds. The crops like Sugarcane, Vegetables, Pulses, Fruits, Rice and Grains are economically useful crops selected for the analysis of AD in the region. Rice, *Nagali* and *Varai* are *rainfed* crops observed on hilly slopes and foothills areas (Su *et al.*, 2014). However, the crops like Sugarcane, Vegetables, Fruits, Grains and Pulses are observed in the eastern part due to development of irrigation facilities in the lands with gentle slopes. The area under Vegetable and Fruit crops is increased in the eastern part of the study region.

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Study area:

Upper section of Mula River basin (19° 03' 45.00" N to 19º 30' 02.00" N and 73º 33' 45.00" E to 74º 37' 31.00" E) in Ahmednagar district (India) within Akole, Sangamner, Parner and Rahuri tehsils was selected for impact analysis of WMPs for AD. The Mula River originates in *Ajoba Dongar*, near *Harishchandragad* located in the Sahyadri range and contributes water to Pravara River. The height varies from 512 to 1472.7 m and rainfall from 239 to 4846 mm. About 86.38% lands classified in the class 0º to 10º, 11.75% in 10º to 22º and 1.57% in 22º to 33º slope. The study area is the part of Deccan trap with compound pahoehoe flows and '*som aa Aa'* flows, Megacryast compound pahoehoe basaltic flows and Alluvium type geology. Slightly deep, well drained, fine, moderately calcareous soils on very gently sloping land are observed (1717.48 km^2) with moderate erosion. Further, very shallow excessively drained, loamy soils (422.85 km^2) on moderately sloping undulating land with severe erosion and strong stoniness are also observed. Rice is the major crop in the *kharif* (rainy) season for the western part of the basin whereas cereals like *Bajra*, Pulses and Groundnuts are observed as major crops in the *kharif* season and *Jawar*, Wheat, Maize and Sunflower, Vegetables in *rabi* (winter) season for eastern part. Western part shows subsistence type of agriculture fully depend on rainfall and only small patches near streams in eastern part observed seasonal irrigation for Vegetables. The Upper Mula basin has been divided into 140 micro-watershed namely SW0 to SW139 (Fig. 2) for analysis purposes.

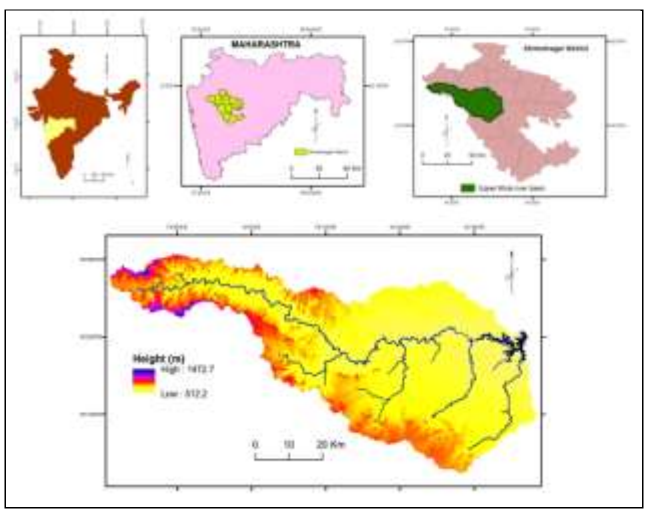

Fig.1 Study area

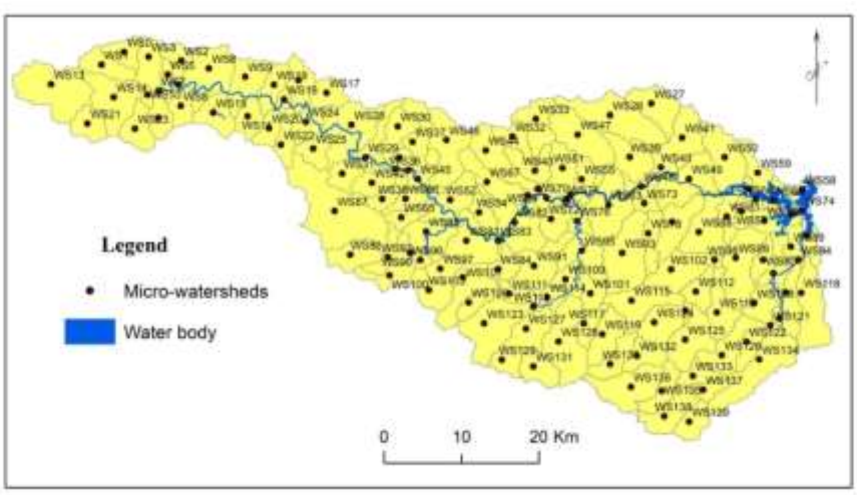

Fig. 2: Micro-watersheds

Methodology

Analytical Hierarchy Process based multi-criteria analysis and influence technique were used for AD of micro-watersheds in Mula River basin. The ranking (Table 1) of the crops have been performed based on experts' opinions collected using remote technique e.g. Google forms. The AD was performed through eight steps: 1) Delineation of micro-watersheds with the help of DEM, 2) Data collection and analysis for selected crops (criterions), 3) Ranking of the criterions, 4) Pairwise comparison matrix analysis, 5) Normalization of pairwise comparison matrix, 6) Calculation of weights, 7) Micro-watersheds wise normalization of calculated influences and 8) Calculation of AD according to the micro-watersheds.

3.1 Data

Data regarding selected crops e.g. Rice, Sugarcane, Vegetables, Grains, Pulses and Fruits was procured from government records available at tehsil offices (Akole, Sangamner, Rahuri and Parner) in Ahmednagar district for the year of 2019 and used for multi-criteria and

AHP analysis to calculate AD in micro-watersheds. GIS layers were prepared based on topographic maps (47E/10, 47E/11, 47E/14, 47E/15, 47I/2, 47I/3, 47I/4, 47I/6, 47I/7, 47I/8, 47I/10, 47I/11 and 47I/12) procured from SOI (Survey of India). ASTER DEM data was used for delineation of micro-watershed boundaries. The data and maps were loaded in GIS software for preparation of thematic layers.

3.2 Selection of criterions

Rice, Sugarcane, Vegetables, Grains, Pulses and Fruits were used for multi-criteria analysis using AHP and influence technique to calculate the AD in the study area. Rice, Sugarcane, Vegetables, Grains, Pulses and Fruits are economically important and principal crops in the region. Therefore, these crops were selected as criterion for assessment of AD.

3.3 AHP analysis for estimation of AD

Agricultural development of micro-watersheds was processed using AHP technique through six steps: 1) Determination of rank (Table 1) with the help of expert opinion, 2) Pairwise comparison, 3) Normalization of PCM of six selected crops, 4) Calculation of weights and influence of crops, 5) Normalization of micro-watersheds wise influences of selected crops and (6) Estimation of AD in micro-watersheds.

Table 1: Ranks: crops

Crops	Sugarcane	Rice	Grains	Pulses	Vegetables	Fruits
Rank	1	5	3	6	2	4

Table 2: Pairwise comparison matrix

Criterion	Sugarcane	Vegetables	Grains	Fruits	Rice	Pulses
Sugarcane	1.00	2.00	3.00	4.00	5.00	6.00
Vegetables	0.50	1.00	1.50	2.00	2.50	3.00
Grains	0.33	0.67	1.00	1.33	1.67	2.00
Fruits	0.25	0.50	0.75	1.00	1.25	1.50
Rice	0.20	0.40	0.60	0.80	1.00	1.20
Pulses	0.17	0.33	0.50	0.67	0.83	1.00
Sum	2.45	4.90	7.35	9.80	12.25	14.70

Table 3: Normalized pairwise comparison matrix

Criterion	Sugarcane	Vegetable	Grains	Fruits	Rice	Pulses	Sum	Weights	Influence %	%
Sugarcane	0.41	0.20	0.14	0.10	0.08	0.07	1.00	0.05	0.41	41
Vegetable	0.20	0.10	0.07	0.05	0.04	0.03	0.50	0.02	0.20	20
Grains	0.14	0.07	0.05	0.03	0.03	0.02	0.33	0.02	0.14	14
Fruits	0.10	0.05	0.03	0.03	0.02	0.02	0.25	0.01	0.10	10
Rice	0.08	0.04	0.03	0.02	0.02	0.01	0.20	0.01	0.08	8
Pulses	0.07	0.03	0.02	0.02	0.01	0.01	0.17	0.01	0.07	7
Sum							2.45	0.12	1.00	100

3.4 Determination of rank

Expert opinion was used for assigning the ranks (Table 1) to criterions selected for weighted analysis (Table 3). The ranks are useful for better understanding of unstandardized factors than the standardized (Bhagat, 2012). Zolekar and Bhagat (2015) have used experts' opinions for ranking the criterions in AHP based weighted overlay analysis for land suitability for AD. 1 to 6 ranks were assigned to selected crops (Table 1) (Ranjan *et al.*, 2013; Zolekar and Bhagat, 2015; Farhan and Anaba, 2016; Argyriou *et al.*, 2016; Gaikwad and Bhagat, 2018). Scholars like Ghanbarpour and Hipel (2011), Rekha *et al.* (2011), Feizizadeh *el al.* (2014), Sepehr *et al.* (2017) have been used multi-criteria decision-making and PCM for AD. PCM has been prepared (Table 4.2) to calculate the weights for calculation of influence for criterions selected (Elaalem, 2012; Zolekar and Bhagat, 2015). The PCM helps to recognize the association between the criterion in relation to groundwater holding capacity, surface erosion and influence in assessment for applications of conservation techniques in the watershed for AD (Emamgholi *et al.*, 2007; Ranjan *et al.*, 2014). The criterion values in PCM were divided by total of the column to find the cell values in normalized PCM (Table 3).

3.5 Weights and influences

Weights and influences were calculated as average of values of criterions in row of normalized PCM to get the weights of criterion (Zolekar and Bhagat, 2015; Maddahi *et al.*, 2017) (Table 3). Further, influences of the criterion selected for AD of micro-watersheds were estimated by calculating the cell values (%) (Gaikwad and Bhagat, 2017) (Equation 1, Table 3).

$$C_i = \frac{W_c}{W_s} \times 100 \qquad (1)$$

C_i = Normalized influence of criterion based on AHP
W_c = Estimated weights of criterion
W_s = Sum of estimated weights for all criterions
C_i = The share of criterion in total influence (100%) of criterion which can be distributed within the criterion according to estimated weights (Gaikwad and Bhagat, 2017).

3.6 Normalized influences

The influences of criterion interpret the share of individual criteria in sum of AD (100 %) and vary according to micro-watersheds (Silva *et al.*, 2007; Gaikwad and Bhagat, 2017). Here, micro-watersheds wise influences of criterion were normalized according to spatial distribution in micro-watersheds (Equation 2) (Gaikwad and Bhagat, 2017).

$NDI_w = \frac{C_w}{C_s} \times C_{di}$ (2)

NDI_w = Watershed wise normalized development influence
C_w = Cell value of criterion for the micro-watershed
C_s = Sum of cell values of criterion
C_{di} = Estimated development influence of criterion based on AHP

3.7 Weighted development

Sugarcane, Vegetables, Grains and Fruits have been widely used for assessment of AD. These crops can be useful to decide overall AD of micro-watersheds (Aher *et al.*, 2014) using normalized PCM (Ghanbarpour and Hipel, 2011), calculated influences (Table 3) for criterion and watershed wise normalized influences (Gaikwad and Bhagat, 2017).

$AD_w = \sum_{i=1}^{n} NI_w$ (3)

AD_w = Agricultural development of micro-watersheds
NI_w = Watershed wise normalized influence
n = Number of criterion
i = Criterion

1. Criterions

4.1 Rice

Rice is an important crop in *kharif* season on 24.50% NSA in western hilly region with higher rainfall (Su *et al.*, 2014) whereas no Rice cultivation was observed in the eastern part having less rainfall. Micro-watersheds, WS23 (73.21%), WS12 (69.47%), WS10 (52.28%) and WS8 (50.44%) show more than 50% NSA under Rice. 6 micro-watersheds shown less influence of Rice cultivation and two micro-watersheds show moderate influence.

Table 4: Distribution of area under Rice

Classes	Influence (%)	Watersheds
< Mean-1STD	00	115
Mean-1STD to Mean	< 0.06	06
Mean to Mean + 1STD	0.06 to 0.22	02
Mean + 1STD to Mean + 2STD	0.24 to 0.38	05
>Mean + 2STD	>0.38	12
Total		140
Mean		0.06
STD		0.16
Maximum		0.76
Minimum		00

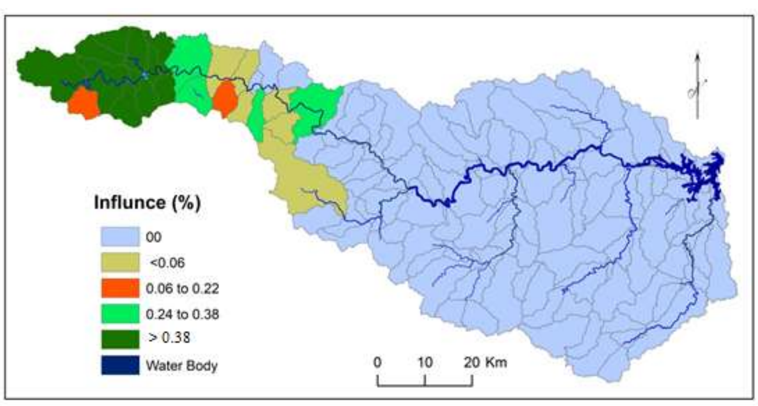

Figure 3: Rice

These micro-watersheds are located in western part with high rainfall, steep slope, thin soil layer and high erosion. 12 micro-watersheds show more Paddy cultivation in the villages viz: Wagdari, Tale, Lavali Kotul, Kothale (WS23), Pimpri, Shinde, Vihir, Kohane (WS12), Pimpri, Purushawadi, Khadki Bk., Khadki Kh. (WS10), Khadki Kh., Wanjulset and Somalwadi (WS8). All these micro-watersheds are located in western part with high rainfall, moderate to

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steep slopes, marginally deep and extremely drained loamy soils and slightly deep good drained well calcareous soils and moderate erosion (Table 4, Figure 3)

4.2 Sugarcane

Sugarcane is a significant crop for tropical and sub-tropical regions (Driemeier *et al.*, 2016; Karpagam *et al.*, 2019). It is one of the economically important crops and has significant effect on the rural economy (Chandra *et al.*, 2018). The impacts of Sugarcane on the environment and society depend on the nature of rural economy (Gupta *et al.*, 2018). It is high influence crop with significant positive and negative ecological and socioeconomic impacts in the region (Hess *et al.*, 2016). Sugarcane is an economically important crop (Chogatapur *et al.*, 2017; Kona *et al.*, 2019) in the irrigated area of the *rainfed* region.

Table 5: Distribution of area under Sugarcane

Classes	Influence (%)	Watersheds
< Mean-1STD	00	101
Mean-1STD to Mean	< 0.29	15
Mean to Mean + 1STD	0.29 to 1.10	12
Mean + 1STD to Mean + 2STD	1.10 to 1.91	02
>Mean + 2STD	>1.91	10
Total		140
Mean		0.29
STD		0.81
Maximum		4.31
Minimum		00

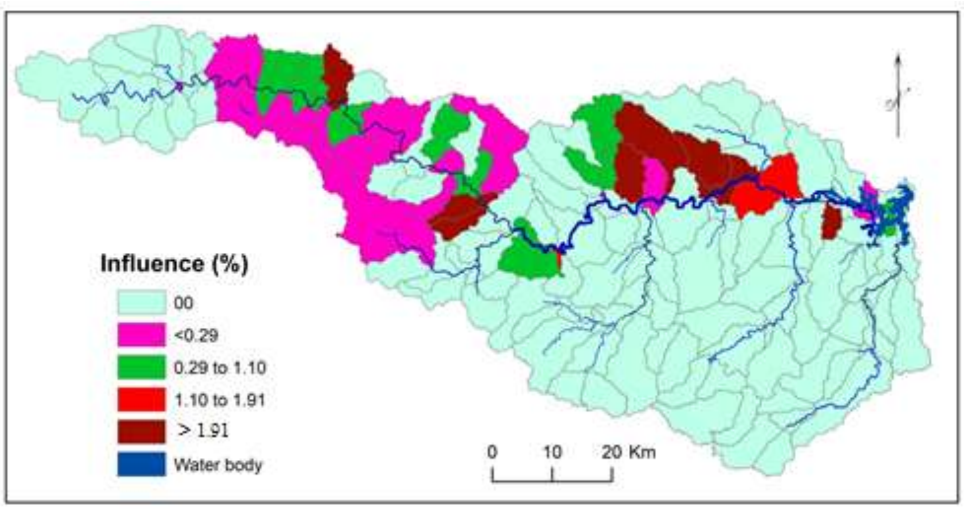

Figure 4: Sugarcane

About 12 micro-watersheds show 5.57% NSA with high and very high Sugarcane cultivation in downslope region in the East. Similar observation was reported by (Kulkarni and Subramanian, 2014) in case of Sugarcane cultivation in Mula and Mutha river basins, Maharashtra, India. Mogras, Dhamangaon Pat and Kotul villages of Akole tehsil, Shindodi Khambe, Darewadi, Bhojadari and Kumbharwadi villages in Sangamner tehsil and village Jambhali in Rahuri tehsil observed less (< 0.29) influence of Sugarcane cultivation. 2 micro-watersheds of the villages Shindodi Khambe, Darewadi, Bhojadari and Kumbharwadi in Sangamner tehsil Pangari of Akole tehsil and Jambhali in Rahuri tehsil show the higher Sugarcane cultivation (Table 5). 12 micro-watersheds show moderate (0.29 to 1.10) influence of Sugarcane cultivation. These micro-watersheds are located in eastern part of the study area with undulating landform, low rainfall, limited irrigation facilities and loamy soils. 2 micro-watersheds were observed with high influence of Sugarcane cultivation (1.10 to 1.91) and 10 micro-watersheds revealed very high (Table 5, Figure 4) influence of Sugarcane cultivation (>1.91) from the central part with moderate rainfall, gentle slope and deep soils. However, Sugarcane cultivation has decreased in the villages like Mogras, Dhamangaon Pat and Kotul and increased by 3.57% NSA in the villages Shiswad, Pimpalgaon Khand, Sherewadi, Thakarwadi and Lingdev of Akole tehsil, Darewadi and Bhojadari villages of Sangamner tehsil and Jambhali in Rahuri tehsil due to successful application of WMPs.

4.3 Vegetables

Vegetables are important cash crops (Perez and Tschinkel, 2003) in the study area. However, it is not observed in the hilly regions (9 micro-watersheds) of the western part of the study area (Table 6) with steep slopes, dense forests and the highland areas. In the villages of Paithan, Ambhol and Kotul, the crops like Tomato, Cabbage, Green bean, Cilantro, Brinjal, etc. are observed due to availability of irrigation facilities from Mula River. In the less rainfall from the eastern part of the study region, Vegetable crops are observed on the lands with irrigation facilities. Six micro-watersheds including villages Mahalwadi, Savargaon Ghule, Sarole Pathar in Sangamner tehsil; Pimpalgaon Turk, Kanhur Pathar, Karandi and Goregaon in Parner tehsil show very high cultivation (>0.37 NSA) of Vegetables. The villages like Belapur, Jachakwadi, Chaitanyapur, Jambhale, Bramhanwada and Kunthewadi in Akole tehsil show high (0.26 to 0.37) influence of Vegetable cultivation (Table 6, Figure 5).

Table 6: Distribution of area under Vegetables

Classes	Influence (%)	Watersheds
< Mean-1STD	< 0.04	18
Mean-1STD to Mean	0.04 to 0.15	65
Mean to Mean + 1STD	0.15 to 0.26	35
Mean + 1STD to Mean + 2STD	0.26 to 0.37	15
>Mean + 2STD	>0.37	07
Total		140
Mean		0.15
STD		0.11
Maximum		0.48
Minimum		00

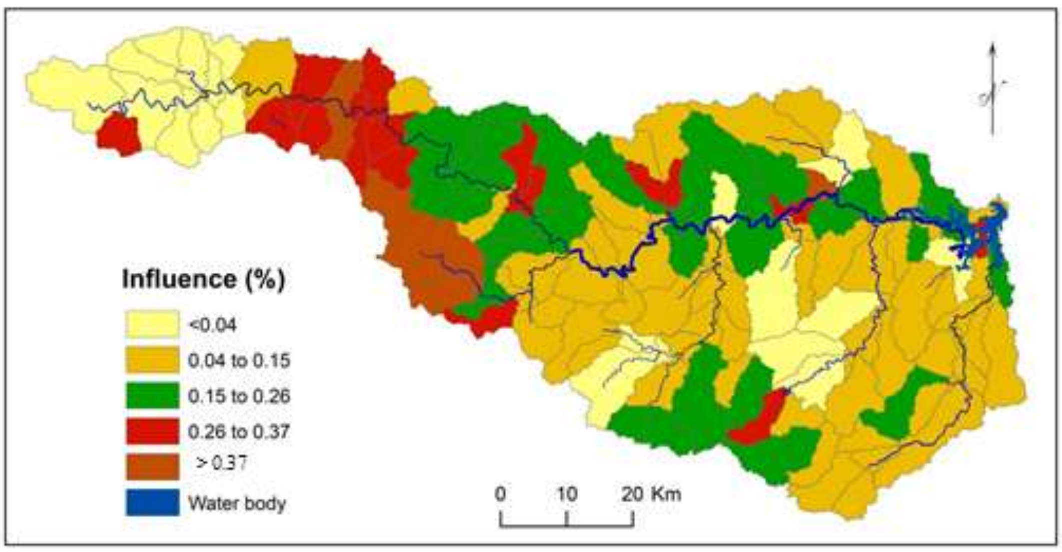

Figure 5: Vegetables

In central part of the study area, Pangari, Kotul, Bholewadi and Mogras villages of Akole tehsil show very high (>0.37) influence of Vegetable cultivation. Vegetable production has increased in Belapur, Jachakwadi, Chaitanyapur, Jambhale, Bramhanwada and Kunthewadi villages due to successful application of WMPs and dam constructed at Pimpalgaon on the Mula River. The use of new technologies for efficient irrigation like drip irrigation, sprinkler and use of mulching paper, availability of markets, transportation facilities and the economic awareness created among the farmers helped to increase the Vegetable production in the study area.

4.4 Grains

Grains are economically important crops in *rainfed* region. Western part of study area show thin soils, steep slopes and high rainfall (*kharif* season) therefore *Ragi, Saya, Nagali, Rala, Varai, Katki, Bantti, Bhadali, Kodara* and *Barly* are observed here. In *rabi* season, Wheat, Maize, *Jawar* and *Bajra* are observed in the region with less rainfall in the eastern part. One watershed show very high (>0.16) influence of cultivation of Grains (Table 7, Figure 6) in villages like Chas, Lahit Kh., Chand Suraj, Lahit Bk., in Akole tehsil and Kauthewadi and Jawale Baleshwar Sangamner tehsil.

In study area, 63 micro-watersheds show moderate (0.10 to 0.13) influence of cultivation of Grains. This is plateau region with fertile soils and available dug and tub-well irrigation. In Akole tehsil, more lands are under Vegetable cultivation because use of new technologies for efficient irrigation like drip irrigation, sprinkler and mulching paper, availability of market facilities, good transportation facilities and the economic awareness. Therefore, in foothill zone of the study area, the cultivation of Grains is decreasing from some decades. The villages like Khadki Bk., Khadki Kh., Purushawadi, Balthan, Savarkute, Dhamanvan, Shirpunje and Manik Ozar in Akole tehsil and Dhotre Kh., Gajadipur, Wadgaon Sawtal, Dhoki, Takali Dhokeshwar and Dhotre Bk. in Parner tehsil show positive change in Grains cultivation. The villages like Shiswad, Lavhali Kotul, Lavhali Otur, Wagdari, Kothale, Somalwadi, Ghoti, Sakirwadi, Shelad villages show more positive change in the cultivation of Grains.

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Table 7: Distribution of area under Grains

Classes	Influence (%)	Watersheds
< Mean-1STD	< 0.07	18
Mean-1STD to Mean	0.07 to 0.10	58
Mean to Mean + 1STD	0.10 to 0.13	63
Mean + 1STD to Mean + 2STD	0.13 to 0.16	01
>Mean + 2STD	>0.16	00
Total		140
Mean		0.10
STD		0.03
Maximum		0.15
Minimum		0.01

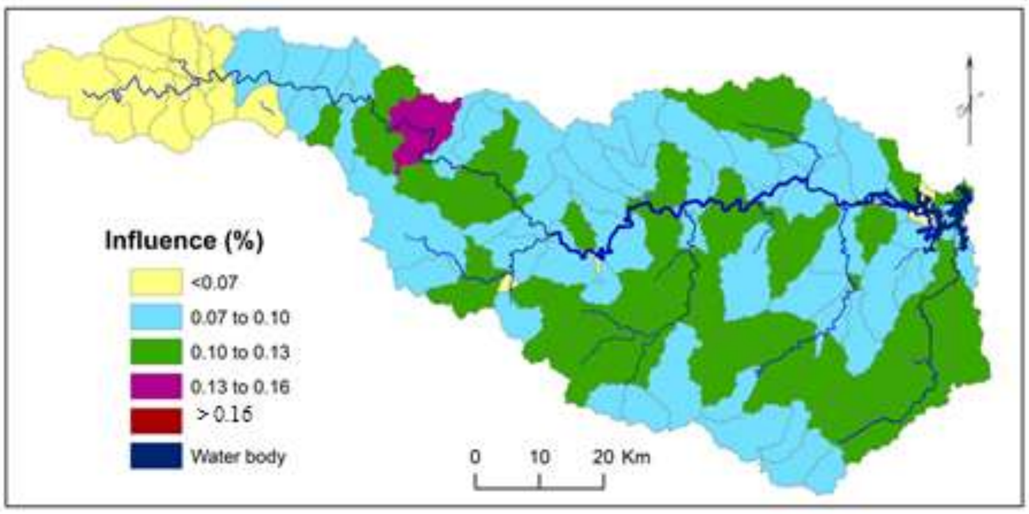

Figure 6: Grains

4.5 Pulses

Pulses like pigeon peas *Toor,* Green gram split *(Moong),* Black gram *(Udid),* Moth bean *(Matki),* Horse gram *(Hulga),* Pink lentil *(Masur), Pawta, Chawali,* Field bean*, Ghevda,* Bengal gram whole *(Harbhara) and Green peas* are an economically important crops in *rainfed* region. These crops are observed in lowlands and well drained soils in the hilly region. In western part of study area with thin soils, steep slopes, high rainfall these crops are observed in *kharif* season including *Hulga, Pawta, Chawali, Wal and Ghevda* and in the eastern part characterized with undulating landforms, less rainfall and loamy soils, Pulses like *Toor, Moong, Udid, Matki, Hulga, Pawta, Chawali* are observed. In Parner tehsil, 2 micro-watersheds including villages like Kaknewadi, Tikol, Pimpalgaon Turk and Kanhur show very high (>0.13) influence of Pulses. 16 micro-watersheds including villages: Shiswad, Ambhol, Pisewadi, Shinde, Bholewadi and Palsunde show high (0.12 to 0.19) influence of Pulses and Darewadi, Kumbharwadi, Varwandi, Kawthe Malkapur, Khambe and Kharshinde villages show high (0.09 to 0.13) influence of Pulses (Table 8, Figure 7). 28 micro-watersheds show very low Pulses cultivation located near to the river bank with deep soils, available irrigation facilities, gentle slope and moderate rainfall. Therefore, these micro-watersheds show cash crop. 58 micro-watersheds show low (< 0.05) influence of Pulses. These micro-watersheds are located in the plateau region with less rainfall, limited irrigation facility and undulating landforms.

Table 8: Distribution of area under Pulses

Classes	Influence (%)	Watersheds
< Mean-1STD	< 0.01	28
Mean-1STD to Mean	0.01 to 0.05	58
Mean to Mean + 1STD	0.05 to 0.09	36
Mean + 1STD to Mean + 2STD	0.09 to 0.13	16
>Mean + 2STD	>0.13	02
Total		140
Mean		0.05
STD		0.04
Maximum		0.17
Minimum		00

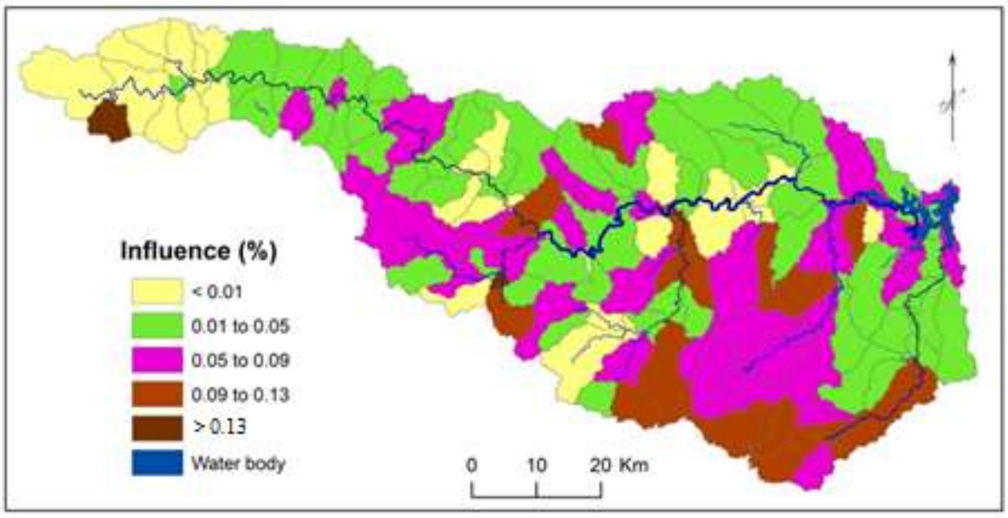

Figure 7: Pulses

4.6 Fruits

Fruits observed on lands with medium slopes, moderately shallow soils, less rainfall and fallow type of land use. Guava, Custard apple, Pomegranate, Chikoo, Banana, Papaya, Mango, Lemon, Watermelon and Grapes are planted in the region which receives less rainfall. Jackfruit, Amla, Black berry, Mango, etc. are observed in the western part have no economic importance for the farmers.

Table 9: Distribution of area under Fruit crops

Classes	Influence (%)	Watersheds
< Mean-1STD	00	36
Mean-1STD to Mean	< 0.07	55
Mean to Mean + 1STD	0.07 to 0.17	35
Mean + 1STD to Mean + 2STD	0.17 to 0.27	05
>Mean + 2STD	>0.27	09
Total		140
Mean		0.07
STD		0.10
Maximum		0.74
Minimum		00

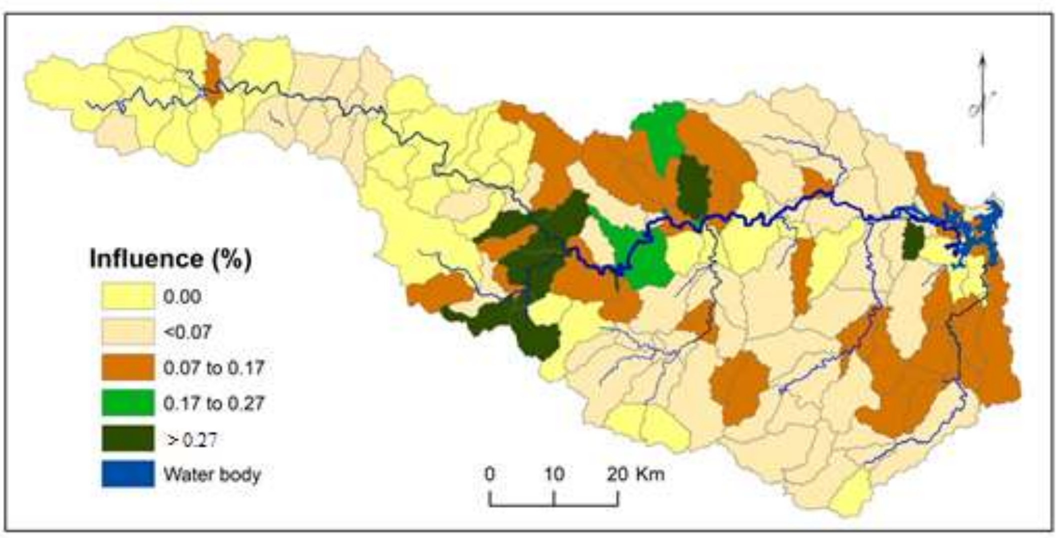

Figure 8: Fruits

The villages like Mhaswandi, Borbanwadi, Pemrewadi, Ambi Khalsa, Ghargaon, Sakur, Rankhambwadi, Kelewadi and Bambalewadi located in 2 micro-watersheds in Sangamner tehsil and Vankute in one watershed area of Parner tehsil show very high (>0.29) influence of Fruits' cultivation (Table 9, Figure 8). Out of 16 villages in Sangamner tehsil and Parner tehsil higher fruit production in the last decade and 61 micro-watersheds show less (< 0.07) influence of Fruits' cultivation. 29 micro-watersheds show moderate (0.07 to 0.18) influence of Fruits' cultivation (Figure 8). These micro-watersheds are located in central plateau region with moderate rainfall, thin soils, undulating landforms and water scarcity.

2. **Agricultural development**

The agricultural development was calculated using multi-criteria based AHP method and influences of criterions. Sugarcane, Vegetables, Pulses, Fruits, Rice and Grains were selected and ranked using expert opinion for estimations of weights and influences. Estimated influences of six criterions were normalized based on spatial distribution in selected micro-watershed for AD in 2019. Estimated levels of AD were classified into three classes: high, moderate and less development (Table 10).

Table 10: Agricultural development

Level of development	No. of watersheds	%
High	11	7.86
Moderate	21	15
Less	108	77.14

5.1 High development

In study area, 11 (7.86%) micro-watersheds (Table 10) are classified into the class 'High development' (>1.56) for agriculture (Figure 9). These micro-watersheds are located near to bank of rivers with gentle slopes, moderate rainfall, accumulated soils and good irrigation facilities. The productivity of these soils is high and economic conditions of the farmers are good.

5.2 Moderate development

About 21 micro-watersheds (15%) are classified into the class, 'Moderate development' with gentle sloping lands (27.80% area) (Table 10) and calcareous soils with moderate erosion. Moderate surface erodibility, less rainfall and droughts are common phenomenon in the region. The population is occasionally migrating for livelihood to irrigated and urban areas.

5.3 Less development

About 108 micro-watersheds (77.14%) in the basin are classified into the class, 'Less development' with low rainfall, low irrigation, undulating surface, low erosion and comparatively less agricultural activity (Table 10). These micro-watersheds are located far away from the major rivers and dams with low groundwater potentials. Therefore, these micro-watersheds show less AD.

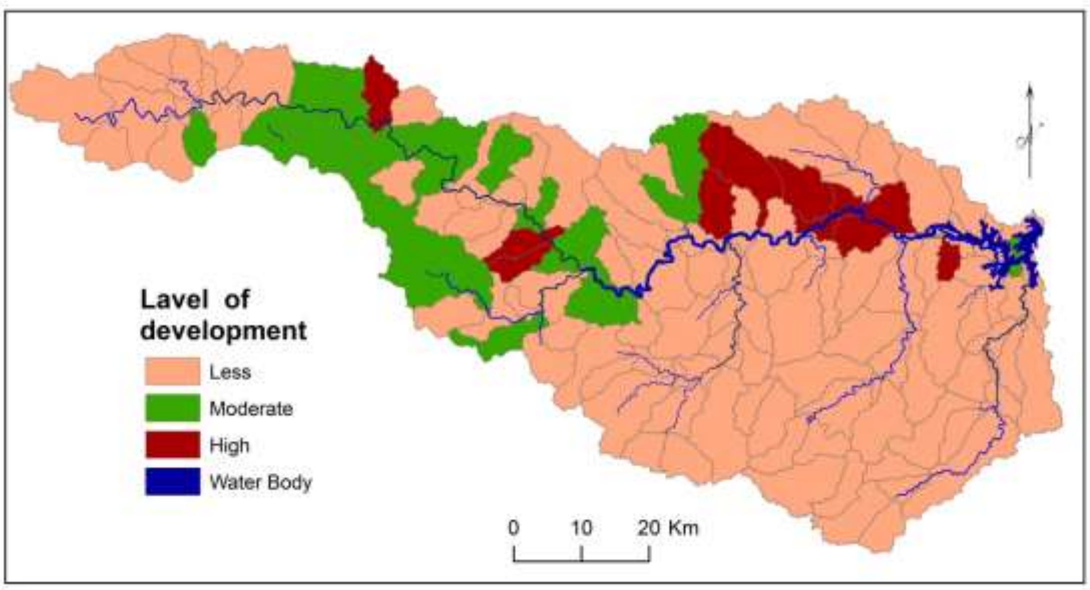

Figure 9: Agricultural development

Conclusions

1. AHP based multi-criteria analysis is useful for agricultural development of sub-watersheds for understanding, planning, management and development.
2. Six criterions i.e. Sugarcane, Vegetables, Pulses, Fruits, Rice and Grains were selected for agricultural development of sub-watersheds in the region.
3. Expert opinion is useful for ranking the criterion for agricultural development of selected watersheds.
4. Influences of criterion were estimated based on weights estimated using AHP methods. These values of influences are normalized using distribution of selected criterion within the sub-watersheds
5. Agricultural development was classified into three categories like: high (), moderate and low development.
6. The methodology formulated in this study can be efficient tool for estimation of agricultural development.

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