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Vegetation Indices Based Spatial Water Demand of Rabi Onion Crop

M. P. Adawadkar [a++*], A. R. Pimpale [b#],
S. B. Wadatkar [c#] ,M. U. Kale [d†] and I. K. Ramteke [e]

[a] *Irrigation and Drainage Engineering, Dr. P. D. K. V., Akola, India.*
[b] *Agricultural Engineering Section, College of Agriculture, Nagpur, India.*
[c] *Department of Irrigation and Drainage Engineering, Dr. P. D. K. V., Akola, India.*
[d] *IDE, Dr. P. D. K. V., Akola, India.*
[e] *Scientific Associate, Maharashtra Remote Sensing and Application Centre, Nagpur, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

There are numerous methods for estimating the water requirements of crops. However, the FAO Penman-Monteith Method has been adopted worldwide but it lacks spatial variability. The accuracy can be improved by adopting VI based method. Therefore, the present study was planned to investigate the use of vegetation indices (VIs) as a surrogate of crop coefficients in place of tabulated crop coefficients and find the best VI in the case of onion crops which require the amount of water. The study was conducted in 3 districts of Maharashtra i.e. Nashik, Dhule, and Jalgaon where onion is a major rabi crop grown on a large scale, for two consecutive rabi seasons of the

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[++] *Ph. D Scholar;*
[#] *Head;*
[†] *Associate Professor;*
**Corresponding author: E-mail: mayur.adawadkar@gmail.com;*

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year 2020-21 and 2021-22. Multitemporal vegetation indices such as NDVI, NDWI, SAVI, MSAVI2, and RVI were estimated using temporal images of Sentinel 2A satellite during the growth period of onion and week-wise values were obtained by using ERDAS Imagine. Linear regression was applied on VI values versus Kc recommended by MPKV, Rahuri which resulted in linear models. NDWI-Kc model showed the strongest relation with high R2 values. The spatial crop evapotranspiration (ETc) was then calculated by applying this model. For the 2020–21 growing season, the total crop evapotranspiration for onions in Dhule, Jalgaon and Nashik was calculated to be 486.5 mm, 482.7 mm, and 488.7 mm, respectively. Whereas during 2021–22, it was estimated to be 493.7 mm, 473.9 mm, and 477.2 mm, respectively in these districts. For getting water demand crop evapotranspiration values were multiplied by the acreage estimated by remote sensing. Total water demand for rabi onion for the districts Dhule, Jalgaon and Nashik was found to be 70.54 Mm3, 43.8 Mm3 and 693.2 Mm3, respectively and 128.1 Mm3, 33.9 Mm3, and 825.7Mm3 respectively for the years 2020-21 and 2021-22, respectively.

Keywords: Crop water demand; crop evapotranspiration; vegetation indices; crop coefficients; Sentinel 2A.

1. INTRODUCTION

Crop water requirement is the amount of water required to compensate for evapotranspiration loss from a planted area which differs substantially amongst crops and also over the growth season of different crops. Accurately estimating crop water requirements is a critical component of agricultural planning [1]. Water use efficiency, which is primarily governed by crop evapotranspiration (ETc), can be improved on a regional scale through proper irrigation planning, scheduling, and decision-making based on estimated ETc, which in turn is affected by crop coefficient (Kc). Though there are various methods for measuring crop evapotranspiration (ETc), the FAO Penman-Monteith methodology [2] is the sole accepted method. This method generates location-specific daily reference evapotranspiration (ETo) using meteorological data, which is then multiplied by crop coefficients (Kc) to compute crop evapotranspiration (ETc) which can be represented by $ET_c = K_c \times ET_o$.

Precision irrigation is a distinctive sustainable agriculture method that allows water and nutrients to be delivered to plants at the right time and in the right place in small calculated doses to generate optimal growing conditions. Precision irrigation management demands determining ETc under a variety of climatic and field conditions. Crop coefficients lack regional variation due to differences in crop variety and growth stage from field to field. As a result, determining a regional water need for a specific period is difficult task. Identifying geographical and temporal changes in water use is quite complicated with current crop coefficient techniques.

Estimation of water requirements by utilizing remote sensing may prove the most precise and time-efficient technique for irrigation water management. Vegetation Indices (VIs), which are measured as differences, ratios or linear combinations of reflected light in the visible (blue, green or red) and near- infrared (NIR) bands, are substantially related to a range of crop growth factors (Moran et al., 1995). Many scientists have observed parallels between the temporal patterns of Kc and VI. As a result, Kc can be calculated using VI and used to estimate crop water requirements. Weekly or biweekly VI extraction can provide more precise Kc, allowing for irrigation scheduling in near-real time.

This study delves into the optimization of water management strategies in rural agricultural territories of developing countries, particularly focusing on the cultivation of rabi onion crops in Maharashtra, India. Water scarcity poses a significant challenge to agricultural sustainability [3], especially in regions where traditional methods of water estimation and management fall short [4,5]. By employing remote sensing techniques and vegetation indices (VIs), the research aims to enhance the precision and spatial variability of estimating crop water requirements [6].

The FAO Penman-Monteith Method, while widely used, is criticized for its lack of spatial resolution, making it less effective in heterogeneous agricultural landscapes [7]. Here, the study presents a viable alternative by integrating VIs derived from Sentinel 2A satellite imagery. This modern approach not only improves accuracy but also offers a scalable solution that can be adapted to diverse agricultural settings [8].

The onion (*Allium cepa* L.), often known as bulb onion, is a popular vegetable. India is the world's second-largest producer of onions, trailing only China. Maharashtra is India's biggest onion producer, followed by Madhya Pradesh, Karnataka, and Gujarat [9,10]. Onion requires a huge amount of water throughout its growth period. Taking into account all of the advantages of remotely sensed data in precision irrigation management, this study focused on integrating the VI-based Kc within the framework of FAO methodologies for forecasting real-time spatial water usage patterns to establish the ideal irrigation plan resulting in the saving of water.

2. MATERIALS AND METHODS

2.1 Study Location

The study was carried out in three districts of North Maharashtra i.e. Nashik, Dhule and Jalgaon which are situated between 73° 78' 98" E to 75° 52' 77" E longitude and 19° 99' 75" N to 21° 03' 96" N latitude covering an area of 34542 km^2 as shown in Fig. 1.

2.2 Remote Sensing Data

Sentinel 2A satellite images were used for this study. The data is publicly available for download via the Sentinel Scientific Data Hub website. Sentinel 2A satellite produces multi-date, multi-spectral images that have finer resolutions of 10 m, 20 and 60 m. Ten images of 10 m resolutions study area were downloaded for two *rabi* seasons of years 2020-21 and 2021-22 each at approximately of 10-day intervals.

2.3 Ground Truth Data Collection

The ground truth data was collected during the field visits organized during the growth period of the crops. Information about the crop, its growth, area of crop field, date of planting, number of irrigations applied, etc was taken from the farmers, if available. The ground truth data of 26 and 28 locations were taken during the *rabi* season of 2020-21 and 2021-22, respectively.

2.4 Weather Data Collection

The weekly meteorological data of the study area was collected from the website of NASA Power [1]. The weather data consisted of maximum temperature, minimum temperature, mean relative humidity, solar radiation, wind speed and rainfall.

2.5 Image Processing

Multi-date images from the sentinel 2A satellite were processed in the ERDAS Imagine and ArcGIS 10.2 environment. These were stacked together with option of Layer stack in ERDAS Imagine software. Afterward, these stacked images were subseted and clipped to get a single multispectral image. By using an unsupervised classification menu, Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil Adjusted Vegetation Index (SAVI), Modified Soil Adjusted Vegetation Index 2 (MSAVI2) and Ratio Vegetation Index (RVI) were generated. 10 images of each vegetation index were stacked together which resulted in a total of 10-layer stacks for each layer.

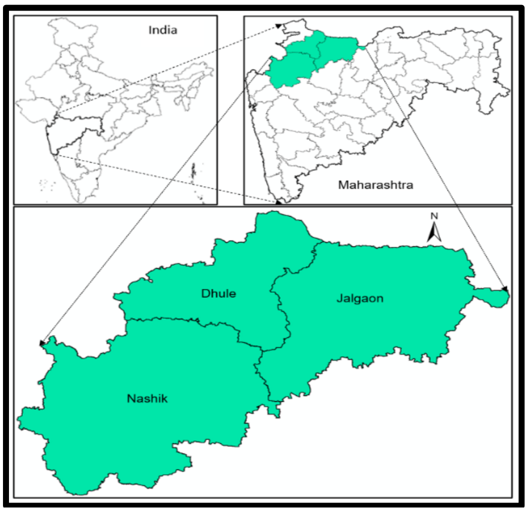

Fig. 1. Study area

2.6 Generation of VI-Kc Model

Obtained week-wise VIs and crop coefficients recommended by MPKV, Rahuri for onion crops were correlated by using linear regression analysis. VI-Kc models were developed by using statistical analysis which includes Coefficient of determination (R^2), Root Mean Square Error (RMSE), Percent Deviation (D) and Willmott Index of agreement.

2.7 Estimation of Water Demand

FAO Penman-Monteith equation was used to estimate reference evapotranspiration (ETo) with the help of weekly meteorological data obtained from the NASA Power system. With the help of the best VI-Kc model, week-wise crop coefficients were calculated. The week-wise water requirements (ETc) were obtained by the product of reference evapotranspiration and VI-based crop coefficient. Finally, the total water demand of the study area was estimated by product of onion acreage obtained by remote sensing technique and crop evapotranspiration (ET_c).

3. RESULTS AND DISCUSSION

For the *rabi* season of 2020-21 and 2021-22, Multispectral images were downloaded and processed in the ERDAS Imagine environment and estimated different vegetation indices which showed strong correlation. From the stack layer images of vegetation indices viz. NDVI, NDWI, SAVI, MSAVI2 and RVI the values corresponding to different stages of the crop were distributed after regression analysis of VI with 5 models of crop coefficients were obtained. Out of these vegetation indices NDWI-Kc model showed the strongest relationship with crop coefficients for both years 2020-21 and 2021-22. Multi-date and temporal vegetation indices were extracted and tabulated week-wise as given in Tables 1 and 2. The reference evapotranspiration (ET_o) was calculated with the help of the Penman-Monteith method by using meteorological data for both the years 2020-21 and 2021-22 as shown in Tables 3 and 4 respectively. NDWI-Kc was then multiplied with reference evapotranspiration to obtain the crop evapotranspiration (ET_c) as given in Tables 5 and 6 for both years 2020-21 and 2021-22, respectively. Finally, water demand was estimated by multiplying crop evapotranspiration with onion crop acreage obtained by remote sensing method for the years 2020-21 and 2021-22 as depicted in Tables 7 and 8.

NDWI-K_c model showed the highest R^2 and D values of 0.91 and 0.98 for the year 2020-21, 0.87 and 0.97 for the year 2021-22 followed by SAVI-K_c which had R^2 and D values of 0.85 and 0.96 for 2020-21, 0.84 and 0.96 for 2021-22. NDWI-K_c model showed lower values of SE, RMSE and PD of 0.069, 0.065 and 0.85 (2020-21), 0.083, 0.077 and 1.14 (2021-22).

Table 1. Average weekly values of VIs of onion for *rabi* season of 2020-21

Weeks past sowing	NDVI	NDWI	SAVI	MSAVI2	RVI
1	0.126	0.017	0.188	0.221	1.291
2	0.161	0.026	0.242	0.271	1.409
3	0.165	0.032	0.247	0.279	1.405
4	0.195	0.039	0.297	0.321	1.539
5	0.231	0.041	0.348	0.364	1.662
6	0.247	0.121	0.370	0.392	1.669
7	0.313	0.149	0.471	0.471	1.960
8	0.320	0.162	0.460	0.466	1.971
9	0.387	0.221	0.580	0.554	2.309
10	0.405	0.227	0.608	0.575	2.440
11	0.398	0.220	0.594	0.556	2.397
12	0.369	0.206	0.549	0.526	2.240
13	0.391	0.229	0.575	0.561	2.303
14	0.332	0.159	0.444	0.487	2.083
15	0.294	0.044	0.305	0.365	1.612
16	0.220	0.033	0.348	0.392	1.839

Table 2. Average weekly values of VIs of onion for rabi season of 2021-22

WPS	NDVI	NDWI	SAVI	MSAVI2	RVI
1	0.136	0.011	0.214	0.243	1.413
2	0.162	0.024	0.221	0.254	1.433
3	0.170	0.027	0.237	0.261	1.437
4	0.160	0.047	0.244	0.271	1.475
5	0.189	0.053	0.294	0.324	1.523
6	0.199	0.063	0.298	0.331	1.549
7	0.202	0.076	0.291	0.334	1.526
8	0.208	0.113	0.308	0.337	1.528
9	0.242	0.141	0.362	0.387	1.639
10	0.270	0.157	0.402	0.422	1.712
11	0.252	0.152	0.354	0.379	1.647
12	0.253	0.145	0.398	0.409	1.689
13	0.238	0.124	0.364	0.388	1.659
14	0.235	0.113	0.336	0.384	1.641
15	0.204	0.080	0.293	0.339	1.536
16	0.181	0.048	0.251	0.294	1.494

Table 3. Reference evapotranspiration (ET_o) of different districts of the study area in the *rabi* season of 2020-21

Met. Week	Reference evapotranspiration (ET_o) (mm)		
	Dhule	Jalgaon	Nashik
45	3.56	3.29	3.51
46	3.47	3.25	3.16
47	3.31	3.16	3.07
48	3.48	3.31	3.22
49	3.86	3.64	3.65
50	2.49	2.42	2.27
51	3.46	3.31	3.42
52	3.59	3.44	3.37
1	3.21	3.25	2.57
2	3.64	3.49	3.21
3	4.08	4.30	3.90
4	4.21	4.33	4.54
5	4.91	5.12	4.76
6	4.95	5.00	5.42
7	4.82	4.77	4.72
8	5.34	5.24	5.44
9	6.45	6.22	6.28
10	5.72	5.49	6.32
11	5.87	5.82	6.46
12	5.82	5.92	6.23

The total crop evapotranspiration (ET_C) of onion for Dhule, Jalgaon and Nashik for the year 2020-21 was found as 486.5 mm, 482.7 mm and 488.7 mm respectively. For years 2021-22, Total crop evapotranspiration of Dhule, Jalgaon and Nashik was found as 493.7 mm, 473.9 mm and 477.2 mm respectively. The difference in ET_c of onion crops for both years at different places is because of variation in reference evapotranspiration which depends on the condition of weather and physiology of the area.

Water demand for *rabi* onion for Dhule, Jalgaon and Nashik for the year 2020-21 was estimated as 70.54 Mm^3, 43.80 Mm^3 and 693.23 Mm^3 respectively and for the year 2021-22, water demand was found as 128.16 Mm^3, 33.94 Mm^3 and 825.76 Mm^3 respectively. The highest water demand for *rabi* onion was found in Nashik district due to the highest acreage of onion cultivation.

The comparison of multiple vegetation indices, including NDVI, NDWI, SAVI, MSAVI2, and RVI, underscores the importance of selecting the most appropriate index for accurate estimation [11]. By establishing linear models between VIs and crop coefficients (Kc), the research demonstrates a robust methodology for predicting spatial crop evapotranspiration (ETc), a critical parameter in water management [12], (Lopez and Olivares, 2020).

Table 4. Reference evapotranspiration (ET_o) of different districts of the study area in the *rabi* season of 2021-22

Met Weeks	Reference evapotranspiration (ET_o) (mm)		
	Dhule	**Jalgaon**	**Nashik**
45	3.53	3.17	3.11
46	3.31	2.92	2.95
47	3.08	2.84	2.75
48	3.00	2.73	2.71
49	2.74	2.53	2.49
50	3.04	2.85	2.61
51	3.18	2.95	2.97
52	3.17	2.82	3.06
1	3.37	3.06	2.90
2	3.55	3.07	2.81
3	4.13	3.67	3.61
4	4.20	3.84	3.77
5	4.77	4.50	4.44
6	4.73	4.67	4.81
7	4.79	4.82	4.94
8	5.51	5.35	5.75
9	5.50	5.55	6.08
10	5.39	5.64	5.46
11	7.39	7.27	7.44
12	7.94	7.45	7.03

Table 5. Crop evapotranspiration (ET_c) for *rabi* onion of 2020-21

Weeks past Transplanting	Crop evapotranspiration (ET_c), mm		
	Dhule	**Jalgaon**	**Nashik**
1	18.24	17.18	17.25
2	12.16	11.80	11.07
3	17.24	16.50	17.05
4	18.38	17.57	17.25
5	16.53	16.76	13.23
6	23.87	22.83	21.05
7	28.79	30.30	27.52
8	30.58	31.48	33.00
9	40.74	42.52	39.49
10	41.63	42.11	45.58
11	39.93	39.51	39.09
12	42.95	42.12	43.75
13	54.44	52.47	53.01
14	41.30	39.67	45.60
15	30.58	30.33	33.65
16	29.16	29.63	31.19
Total	**486.52**	**482.77**	**488.79**

Table 6. Crop evapotranspiration (ET_c) for *rabi* onion of 2021-22

Weeks past Transplanting	**Crop evapotranspiration (ET_c) (mm)**		
	Dhule	**Jalgaon**	**Nashik**
1	11.91	11.00	10.84
2	14.36	13.47	12.31
3	15.29	14.17	14.28
4	17.11	15.24	16.53
5	18.78	17.00	16.13
6	20.82	18.05	16.47
7	25.86	23.00	22.65
8	30.89	28.31	27.77
9	39.03	36.81	36.35
10	40.89	40.39	41.63
11	40.78	41.03	42.04
12	45.68	44.38	47.64
13	42.19	42.52	46.61
14	39.75	41.55	40.26
15	47.18	46.44	47.51
16	43.22	40.54	38.27
Total	**493.74**	**473.91**	**477.29**

Table 7. Crop Water demand (m^3) in various districts of the study area for *rabi* onion of 2020-21

Weeks past Transplanting	**Water demand of onion (m^3) (2020-21)**		
	Dhule	**Jalgaon**	**Nashik**
1	3014882.4	1779829.9	28211358
2	2010196.2	1222217.3	18108133
3	2849983.5	1708739.5	27873060
4	3037614.7	1820579.4	28201625
5	2732098	1736344.5	21636874
6	3945120.3	2364782.2	34424159
7	4758918.3	3138436.4	44996873
8	5053924.3	3260841.9	53965072
9	6734525.6	4404245.7	64568869
10	6881813.7	4361983.7	74532106
11	6599444	4092883	63912959
12	7098548.6	4363206.1	71544267
13	8998751.4	5435520.3	86682316
14	6826123.8	4109664.7	74570387
15	-	-	-
16	-	-	-
Total (m^3)	70541945	43799275	693228061
Mm^3	**70.54**	**43.80**	**693.23**

Mm^3*- *Million Cubic Meters

Since water is needed only up to physiological maturity, water demand calculations are done only up to the 14th week

The findings reveal the significant potential of NDWI-Kc models, exhibiting strong relationships with high R^2 values, thereby enhancing the reliability of water demand estimations. By extrapolating ETc values to agricultural acreage using remote sensing data, the study provides actionable insights into the total water demand for rabi onion cultivation in different districts across multiple cropping seasons.

In the context of contemporary agricultural challenges, such as climate change and water scarcity [13], this research offers valuable contributions to sustainable water management practices [14]. By leveraging cutting-edge technologies and scientific methodologies [15], the study not only enhances agricultural productivity but also promotes resource-efficient farming techniques, crucial for the socio-economic development of rural communities in developing countries [16,17].

Table 8. Crop Water demand (m^3) in various districts of the study area for *rabi* onion of 2021-22

Weeks past Transplanting	**Water demand of onion (m^3) (2021-22)**		
	Dhule	**Jalgaon**	**Nashik**
1	3786014.0	964960.5	22857521.7
2	4561503.9	1181384.1	25973750.3
3	4857527.0	1242784.9	30116790.8
4	5438260.1	1336978.1	34868709.1
5	5966885.5	1491508.5	34010584.4
6	6614590.9	1583054.9	34745700.0
7	8215855.2	2017740.3	47768252.4
8	9816610.2	2483111.2	58573464.0
9	12403539.1	3228903.8	76663438.0
10	12994190.2	3542181.7	87811588.3
11	12958838.5	3598855.9	88662033.9
12	14515027.5	3892437.4	100485721.7
13	13405884.7	3729532.7	98312514.9
14	12629369.6	3644173.1	84912390.9
15	-	-	-
16	-	-	-
Total (m^3)	128164096.5	33937607.16	825762460.3
Mm^3	**128.16**	**33.94**	**825.76**

Comparing this study with existing research on water demand and agro-environmental factors in rural agricultural territories of developing countries elucidates several key distinctions and advancements [18,19]. Traditional approaches often rely on simplistic water estimation models, overlooking the spatial heterogeneity inherent in agricultural landscapes [20,21]. In contrast, this study integrates remote sensing data and vegetation indices to capture the dynamic interactions between crops and environmental factors [22,23,24].

While previous studies may provide generalized estimations of water demand, this research offers a more nuanced understanding by incorporating spatial variability through VI-based models [25,26,27]. By analyzing multiple VIs and establishing empirical relationships with crop coefficients [28], (Paredes et al. 2023), the study achieves higher accuracy in estimating crop evapotranspiration, thereby enabling more precise water management decisions [29,30,31].

Furthermore, the comparison highlights the scalability and adaptability of the proposed methodology. By utilizing freely available satellite imagery and established analytical techniques, the approach presented in this study can be easily replicated and customized for different crops and regions, facilitating widespread adoption and implementation.

4. CONCLUSION

An integrated strategy utilizing remote sensing and GIS may be used to provide the precise amount of irrigation water at various places by the actual crop water demand resulting in effective irrigation water management. This technique may also be applied in cases of water shortage to provide the ideal irrigation water as a lifesaving irrigation to avoid crop failure. An expert system for precise irrigation scheduling may be created using real-time, high-resolution data from distant sensors and automated weather stations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Anonymous. Meteorological data. NASA Power Data; 2022.
   DOI:www.power.larc.nasa.gov.in

2. Allen RG, Pereira LS, Raes O, Smith M. Crop evapotranspiration guidelines for computing crop water requirements. FAO Irrigation and Drainage paper 56. Food and Agriculture Organization of the United Nations.ons: Rome, Italy; 1998.
3. Campos BO. Banana production in Venezuela: Novel solutions to productivity and plant health. Springer Nature; 2023. Available:https://doi.org/10.1007/978-3-031-34475-6
4. Hernández R, Olivares B, Arias A, Molina JC, Pereira Y. Identification of potential agroclimatic zones for the production of onion (*Allium cepa* L.) in Carabobo, Venezuela. Journal of the Selva Andina Biosphere. 2018b;6(2):70-82. Available:http://www.scielo.org.bo/pdf/jsab/v6n2/v6n2_a03.pdf
5. Hernandez R, Olivares B, Arias A, Molina JC, Pereira Y. Eco-territorial adaptability of tomato crops for sustainable agricultural production in Carabobo, Venezuela. Idesia. 2020;38(2):95-102. Available:http://dx.doi.org/10.4067/S071834292020000200095
6. Hernández R, Olivares B, Arias A, Molina JC, Pereira Y. Agroclimatic zoning of corn crop for sustainable agricultural production in Carabobo, Venezuela. Revista Universitaria de Geografía. 2018a;27(2): 139-159. Available:https://n9.cl/l2m83
7. Hernández R, Olivares B. Application of multivariate techniques in the agricultural land's aptitude in Carabobo, Venezuela. Tropical and Subtropical Agroecosystems. 2020;23(2):1-12. Available:https://n9.cl/zeedh
8. Hernández R, Olivares B. Ecoterritorial sectorization for the sustainable agricultural production of potato (*Solanum tuberosum* L.) in Carabobo, Venezuela. Agricultural Science and Technology. 2019;20(2):339-354. Available:https://doi.org/10.21930/rcta.vol20_num2_art:1462
9. Anonymous. Crop statistics. Department of Agriculture, Maharashtra; 2021. DOI:www.krishi.maharshtra.gov.in
10. Anonymous. Crop statistics. Department of Agriculture, Maharashtra; 2022. DOI:www.krishi.maharshtra.gov.in
11. López-Beltrán M, Olivares B, Lobo-Luján D. Changes in land use and vegetation in the agrarian community Kashaama, Anzoátegui, Venezuela: 2001-2013. Revista Geográfica De América Central. 2019;2(63):269-291. DOI: https://doi.org/10.15359/rgac.63-2.10
12. Lobo D, Olivares B, Cortez A, Rodríguez MF, y Rey JC. Socio-economic characteristics and methods of agricultural production of indigenous community Kashaama, Anzoategui, Venezuela. Rev. Fac. Agron. (LUZ). 2017;34(2):187-215. Available:https://n9.cl/p2gc5
13. Montenegro E, Pitti J, Olivares B. Adaptation to climate change in indigenous food systems of the Teribe in Panama: a training based on CRISTAL 2.0. Luna Azul. 2021;51(2):182-197. Available:https://n9.cl/qwvwz.
14. Rodriguez MF, Olivares B, Cortez A, King JC, Wolf D. Development of alternative rain gauge network information system in rural environments. Case: Anzoategui, Venezuela. University Proceedings. 2016ª;26(4):65-76. DOI:10.15174/au.2016.961
15. Rodriguez M, Olivares B, Cortez A, Vine R, Wolf D, King JC. Temporal analysis of meteorological drought in semiarid localities of Venezuela. UGCcience. 2016b;22(1):11-24. Available:https://doi.org/10.18634/ugcj.22v.1i.481
16. Rodríguez MF, Cortez A, Olivares B, Rey JC, Parra R, Lobo D. Spatiotemporal analysis of precipitation in the state of Anzoátegui and its surroundings. Tropical Agronomy. 2013;63(1-2):57-65. Available:https://n9.cl/14iow
17. Olivares B, Rodríguez MF, Cortez A, Rey JC, Lobo D. Physical natural characterization of indigenous community kashaama for sustainable land management. Acta Nova. 2015;7(2):143-164. Available:https://n9.cl/6gezo
18. Olivares B, Hernández R. Regional analysis of homogeneous precipitation areas in Carabobo, Venezuela. Lasallian Research Magazine. 2019;16(2):90-105. Available:https://doi.org/10.22507/rli.v16n2a9
19. Casana S, Olivares B. Evolution and trend of surface temperature and windspeed (1994 - 2014) at the Parque Nacional Doñana, Spain. Rev. Fac. Agron. (LUZ). 2020;37(1):1-25. Available:https://n9.cl/c815e
20. Olivares B, Zingaretti ML. Application of multivariate methods for the

characterization of meteorological drought periods in Venezuela. Blue Moon Magazine. 2019;48:172:192.
Available:http://dx.doi.org/10.17151/luaz.2019.48.10

21. Cortez A, Olivares B, Parra M, Lobo D, Rey JC, Rodriguez MF. Systematization of the calculation of the Standardized Precipitation Index as a methodology to generate meteorological drought information. Rev. Fac. Agron. (LUZ). 2019; 36(2):209-223.
Available:https://n9.cl/4spjp
22. Olivares B, Parra R, Cortez A. Characterization of precipitation patterns in Anzoategui State, Venezuela. It would be. 2017;3(3):353-3.
Available:https://doi.org/10.17811/er.3.2017.353-365
23. Olivares B, Hernández R, Coelho R, Molina JC, Pereira Y. Spatial analysis of the water index: An advance in the adoption of sustainable decisions in the agricultural territories of Carabobo, Venezuela. Geographic Magazine of Central America. 2018;60(1):277-299.
DOI: https://doi.org/10.15359/rgac.60-1.10
24. Olivares B, Zingaretti ML. Analysis of the meteorological drought in four agricultural locations of Venezuela by the combination of multivariate methods. UNED Research Journal. 2018;10(1):181-192.
Available:http://dx.doi.org/10.22458/urj.v10i1.2026
25. Olivares B, Parra R, Cortez A, Rodriguez MF. Rainfall homogeneity patterns in weather stations of Anzoátegui state, Venezuela. Multiscience Journal. 2012; 12(Extraordinary):11-17.
Available:https://n9.cl/xbslq
26. Olivares B, Zingaretti ML, Demey Zambrano JA, Demey JR. Typification of agricultural production systems and the perception of climatic variability in Anzoátegui, Venezuela. Revista FAVE - Ciencias Agrarias. 2016;15(2):39-50.
Available:https://doi.org/10.14409/fa.v15i2.6587
27. Paredes F, Olivares B, Rey J, Lobo D, Galvis-Causil S. For Science - Journal of Soil Science and Agroclimatology. 2021; 18(1):58-64.
Available:http://dx.doi.org/10.20961/stjssa.v18i1.50379
28. Viloria JA, Olivares BO, García P, Paredes-Trejo F, Rosales A. Mapping projected variations of temperature and precipitation due to climate change in Venezuela. Hydrology. 2023;10:96.
Available:https://doi.org/10.3390/hydrology10040096
29. Cortez A, Olivares B, Parra R, Lobo D, Rodríguez MF, y Rey JC. Description of meteorological drought events in localities of the central mountain range, Venezuela. Ciencia, Ingenierías y Aplicaciones. 2018;I(1):22-44.
DOI:http://dx.doi.org/10.22206/cyap.2018.vlil.pp23-45.
30. Olivares B. Machine learning and the new sustainable agriculture: Applications in banana production systems of Venezuela. Agricultural Research Updates. 2022;42: 133 - 157.
31. Olivares B. Tropical conditions of seasonal rain in the dry-land agriculture of Carabobo, Venezuela. La Granja: Journal of Life Sciences. 2018;27(1):86-102.
Available:http://doi.org/10.17163/lgr.n27.2018.07

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