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Assessment of Irrigation Water Quality for Dry-Season Green Vegetable (Amaranthus crentus L.) Farming in Ondo State, Nigeria

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Abstract

The need to meet the all-year round green vegetable demands of the ever-growing population, especially in the urban and peri-urban towns of Ondo State, has made dry-season irrigation inevitable. Moreover, dry-season green vegetable farming provides an opportunity for smallholder farmers to further extend their cropping season, increase productivity, and ultimately improve their earnings. Thus, the aim of the present study was to carry out an assessment of irrigation water quality for dry-season green vegetable (Amaranthus crentus L.) farming in Ondo State, Nigeria. Ten (10) water samples covering at least three (3) major towns/cities in each of the three senatorial districts were collected from different green vegetable farms across the state during the dry season. Thereafter, samples of water collected were taken to the laboratory for both physicochemical and microbial analyses. Mean values of physicochemical parameters such as pH (6.12), EC (338.8 µS/cm), turbidity (4.03 NTU), TSS (0.428 mg/L), TDS (169.4 mg/L), and BOD (2.141 mg/L) were within the permissible levels, while COD (154 mg/L) and total hardness (135.24 mg/L) were above the limits. Microbial analysis also showed that total viable coliform counts (TVCC) were higher than the recommended limit, while total viable E. coli counts (TVEC) fell below detectable levels. Therefore, it was concluded that the irrigation water used for dry-season green vegetable farming in Ondo State was relatively of good quality, which serves as an encouragement to both farmers and consumers of the vegetable. However, given the higher levels of total hardness and TVCC, continuous monitoring and assessment of irrigation water quality in the state, especially beyond the areas presently covered, and awareness campaigns against urban surface water pollution to prevent potential faecal contamination of the sources and avert possible ingestion of pathogenic organisms through the consumption of green vegetables are recommended.

Keywords: Assessment, Water Quality, Irrigation, Dry-season, Green Vegetable, Ondo State

1. Introduction

A major impact of the prevailing global climate change, according to the Intergovernmental Panel on Climate Change (IPCC, 2007) [9], is high rainfall variability. The climate of Nigeria is described by two seasons: The rainy and dry-seasons. While the rainy season starts in March/April in most parts of the south and ends in October/November, the dry season commences in November/December and lasts until the following March/April. But the rainy season does not usually commence until June/July in most parts of northern Nigeria. Ondo State is located in the southwestern part of the country. Meanwhile, one of the most visible results of rainfall variability in recent times has been changes in the length of both the rainy and dry seasons from year to year in Nigeria. In most recent years, a shortening of the rainy season has been observed in many parts of the country, including Ondo State, triggering the need for dry-season irrigation farming to meet up with the growing demands for food crops, including vegetables.

As rainfed agriculture is mostly practised amongst many farmers in Nigeria, an inadequate supply of rainfall requires that farmers find an alternative way to supplement the natural supply in order to ensure year-round productivity and food security. Besides, the increasing population in many urban and peri-urban cities in Nigeria has heightened the competition for the available freshwater supply amongst the various sectors of the economy, thus reducing the quantity of water available for agriculture. Certainly, with the growing population, food demand is expected to increase, thereby creating more challenges in the area of crop production. This is particularly important for vegetable production, especially green vegetables (*Amaranthus crentus L.*) that are consumed throughout the year in all parts of Ondo State and widely sought for during the dry-season.

Green vegetable is an important leafy vegetable widely grown and commonly used for soup preparation all over Nigeria and, particularly, in Ondo State. Many scientists have highlighted the importance of vegetables as major and efficient sources of micronutrients in African diets (Adebooye and Opabode, 2004; Ojo *et al*., 2011; Adeagbo and Adejumo, 2020) [3, 18, 2]. For example, Ibekwe and Adesope (2010) [10] stated that vegetables are nourishing foods because they contain a little of all the nutrients needed by man; protein, mineral salts, sugars, vitamins, aromatics, iron, and essential oils that are capable of increasing man's resistance to disease. For this reason, the joint Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) experts consultation on the diet, nutrition, and prevention of chronic diseases, recommended the intake of a minimum of 400 g of fruit and vegetables per day (excluding potatoes and other starchy tubers) for the prevention of chronic diseases, including heart diseases, cancer, diabetes, and obesity, especially in less developed countries (WHO, 2003) [25].

Consequently, green vegetables are widely grown by many farmers in Nigeria, particularly in Ondo State, during the rainy season when they are intercropped with various annual crops. As a result, it is comparatively cheaper during the period than the dry season in many parts of the state and beyond. According to Adeagbo and Adejumo (2020) [2], during the rainy season, there is usually high production of vegetables, which leads to saturation of the market, but the dry season is shrouded in acute scarcity of this important farm produce, thereby leading to a hike in price. This high price of the product during the dry-season is an attraction for many people in the urban and peri-urban cities of Nigeria, where many smallholder farmers, civil servants, artisans, and unemployed youths are engaged in the production of green vegetables as a brisk business. Some other encouraging factors include the small land requirement for its cultivation, as production can take place on patch lands along stream channels and abandoned building plots; fewer diseases; and the short period of maturity.

However, for a good harvest, dry-season vegetable are usually irrigated, and water application is typically achieved using different methods, including manual spaying of water with buckets or basin, watering cans, and drainage channels (Ojo *et al*., 2011) [18]. Adding to this, in a few instances, water application may be done with the aid of portable petrol engine pumps. Nonetheless, the major concern with the dry-season irrigation practice is the quality of the water being used. Because the goal of many dry-season green vegetable farmers is income generation, in many instances, no due cognizance is taken of the quality of water used. Many of the waters used for irrigation are polluted and contaminated; in fact, many farmers are happy to use domestic wastewater because they also add some nutrients to the soil (Aktar *et al*., 2018) [4]. Unfortunately, studies have shown that the quality of irrigation water does not only affect crop yield, but also the internal and external qualities of the product (Zavadil, 2009) [27]. Therefore, the objective of the present study was to assess the quality of irrigation water used for dry-season green vegetable farming in Ondo State, Nigeria.

2. Materials and Method

2.1 The Study Area

Ondo State is located in southwestern Nigeria between the Latitude 5.05 and 8.02 ^{o}N and Longitudes 4.45 and 6.0 ^{o}E. The state is bounded by Ekiti State to the north, Kogi State to the northeast, Edo State to the east, Delta State to the southeast, Ogun State to the southwest, and Osun State to the northwest, and Atlantic Ocean to the south. Ondo State has a total land mass of approximately 15,500 km^2, with well over 70% of it arable, and a population of over 3 million people (NPC, 2006) [17]. The climate of Ondo State varies more than any other states in Nigeria due to its length from the south to the north (1100 km), resulting in the presence of virtually all the climatic belts of Nigeria within its borders. Similar to the country, the climate of the state is controlled by the complex interactions of the maritime air mass, and the continental air mass which annually dictate the onset and cessation of the rainy season, including the varieties of climatic belts from humid (down south) to hype-arid Sahara (far north). Away from the opportunities provided by the public service, Ondo State is naturally agrarian, with a vast majority of the populace engaged in farming of different kinds, such as cash cropping like cocoa plantations, kolanut, cassava, cereals like maize and sorghum, vegetables, and fishery.

2.2 Site Description and Sample Collection

In this study, one sampling site was selected to represent each of the nine (9) federal constituencies of the state. The sites were selected based on their urban status, i.e., the more urbanised towns/cities in each of the constituencies were selected, considering that a greater population of the people is more likely to be affected by the quality of vegetables produced in these locations. In addition, before the actual collection of samples in each of the selected towns, major markets within the metropolis were visited, where vegetable sellers were interviewed to identify the major farm sites supplying the green vegetables being sold. The sites so selected were such that out of the ten (10), eight of them were located on wetland (Table 1.0). Field observations during sampling also showed that apart from the sites in Igbokoda and Akungba, all other sites were located within the municipalities where anthropogenic activities such as open defecation could have had tremendous impacts on water quality and farming activities. In addition, evidence of open grazing and free range were seen around the farm sites, despite the enactment of a law against free range by the Ondo State Government. Out of the lot, six (6) of the sites sourced their irrigation water from nearby streams and drains while the rest four (4) got their water from shallow wells.

Following the above, the permission of the owners of the farm sites was sought to collect the water samples being used for irrigation, while some quantities of the green vegetables were purchased for laboratory analysis. For water sample collection, ten (10) 1 litre plastic containers were used, with one container per site. Before being used, the containers were thoroughly washed with soap and distilled water and allowed to dry, after which the water sample in each site was used to rinse the container before final collection. Samples were transferred to the Chemistry Laboratory at the Federal University of Technology, Akure (FUTA), Nigeria, on the day of collection, where they were adequately refrigerated before the various analyses were carried out. All ten samples were collected in the morning between the last week of February and the first week of March, 2023, which coincides with the peak of the dry season in most parts of the state.

Table 1: Location and description of the sampling sites

S. No	Town	Code	Lat. (ºN)	Long. (ºE)	Source of Water	Site
1	Igbokoda	A	6.35	4.76	Stream	Wetland
2	Okitipupa	B	6.29	4.44	Shallow well	Wetland
3	Ore	C	6.74	4.88	Shallow well	Wetland
4	Ondo	D	7.08	4.82	Stream	Wetland
5	Owena	E	7.19	5.02	Shallow well	Upland
6	Ikare	F	7.54	5.76	Stream	Wetland
7	Akungba	G	7.48	5.75	Stream	Wetland
8	Ogbese	H	7.26	5.38	Stream	Wetland
9	Owo	I	7.24	5.51	Shallow well	Upland
10	Akure	J	7.28	5.20	Stream	Wetland

3. Results and Discussion

3.1 Physicochemical Quality of Water Samples

In–situ observations and measurements revealed that all the samples showed one colour or the other, with diverse odours perceived. Generally, most agencies (local and international) recommend that water for agricultural irrigation should be potable and, therefore, colourless, tasteless, and odourless. The pH of the water samples ranged between 5.40 and 6.73 and were not significantly different from one another (Table 2). The pH values are within the permissible limits of 6.0 to 8.5 for irrigation, as recommended by FAO (2013) [8]. However, about six (6) of the water samples displayed slightly acidic levels, which could be of concern. This is because, at low pH levels, some metals such as Hg, Pb, Cu, and As, may become more soluble, leading to their absorption at higher concentrations into plant tissues, which can ultimately be ingested by consumers (Ashie *et al*., 2024) [7]. Besides, such pH levels in irrigation water can hinder nutrient availability and affect soil structure, thus causing poor plant growth and yield as well as a reduction in microbial activities, which are important for decomposition and nutrient cycling (Li *et al*., 2018) [14]. Moreover, temperatures ranged from 27.60 ºC (F and H) to 28.70 (B), with an average of 28.13 ± 0.42 ºC, which falls within the acceptable limits. Although there is no direct health risk attached to any levels of temperature, high values may indicate increasing microbial activities as a result of organic pollution.

Electrical conductivity (EC) also varied from 44.00 to 870 µS/cm, with a mean of 338.80 ± 276.34, indicating that all the water samples fell below the recommended limits of 3000 µS/cm. This may further imply that irrigation with water from these sources may not pose any threat to the growth of the vegetable (Swistock, 2016) [23]. According to Amankwah *et al*. (2023) [6], high EC is usually a reflection of high salt concentration in water or total hardness and indicates the risk of salinity hazards, an important water quality parameter for crop production. Furthermore, turbidity ranged between 0.30 and 10.20 NTU, with a mean of 4.03 ± 3.10. There were indications of high turbidity levels in at least three of the water samples (B, C, and H), higher than the 5 NTU limit of both the WHO (2006) [26] and the Nigerian Standard for Drinking Water Quality (SON, 2007) [21]. The result also suggests a positive relationship between turbidity and EC, as all the water samples with high turbidity also displayed high levels of EC, with the exception of sample D. Similar results were reported by Oshunsanya and Adeniran (2014) [20] and Ashie *et al*. (2024) [7] in their respective studies at Ibadan, Nigeria, and Kumasi, Ghana. Meanwhile, the application of turbid water in farms may negatively affect the quality of vegetables as it may cause bacteria and virus contamination through solid particles in the water (Jeong *et al*., 2016) [11]. Also, irrigation with highly turbid water can lead to the blockage of stomata, and thereby hamper the ability of the plant to photosynthesize properly, causing poor growth and productivity (Ashie *et al*., 2024) [7]. Nonetheless, the high turbidity of samples B, C, and H is not particularly unexpected given the high rate of anthropogenic activities, including car washing, solid waste deposition, and construction activities, around the water sources.

Total suspended solids (TSS) in the samples ranged from 0.1 mg/l to 1.08 mg/l in samples F to H, with a mean concentration of 0.43 ± 0.34 mg/L. This is far less than those (10.3–90.6 mg/L) reported by Aliyu *et al*. (2017) [5] and Ashie *et al*. (2024) [7] in a similar study in Kwara state, Nigeria, and Kumasi, Ghana, respectively. Mahajan and Gupta (2014) [15] reported the potential of high TSS to impede water movement from soil to plant roots (osmotic potential) through clogging in the roots of plants. TDS which is a measure of all dissolved substances in water, ranged from 22.00 to 435 mg/L, with an average of 169.40 ± 138.37, which also falls within the recommended standard for irrigation water. The results are comparable to those of Sule *et al*. (2021) [22] in a related study on the water quality of a small-scale irrigation scheme in Kwadon, Yamaltu-Deba LGA of Gombe State, Nigeria. Similar to turbidity, it was observed that water sources with high EC also displayed high levels of TDS. The relatively elevated TDS obtained in some of the water samples is attributable to diverse sources of contamination, including urban runoff, soil erosion, and industrial discharges, which may require best management practices, including buffering with vegetation, terracing for erosion control, and sedimentation basins (Mahajan *et al*., 2014) [15]. Nonetheless, Swistock (2016) [23] observed that TDS levels above about 2,000 mg/L may possibly hinder plant growth.

Total hardness in the samples ranged from 25.20 mg/L to 357.00 mg/L, while the mean stood at 135.24 ± 91.11 mg/L, which is far above the standard limits. Generally, water hardness is a function of the calcium and magnesium contents of water which can be significantly influenced by the release of domestic wastewater, especially from laundry and industrial discharges, into surface water. As expected, water samples from C, D, F, and H were from sources highly susceptible to such levels of pollution. High levels of hardness inhibit plumbing system corrosion, while elevated concentrations of hardness above 150 mg/L will build up on contact surfaces, plug pipes, and irrigation lines (Swistock, 2016) [23]. In addition, Sule *et al*. (2021) [22] had earlier reported that hardness in water could hinder vegetable production due to a high pH and absence of some nutrients in the crop. However, given that calcium and magnesium are essential plant nutrients, moderate levels of hardness of 100 to 150 mg/L are considered ideal for plant growth. On the contrary, extremely soft water below 50 mg/L may require the addition of calcium and magnesium fertilizer.

Furthermore, BOD ranged from 1.76 to 2.86 mg/L at sampling points H and C, respectively, with an average of 2.141 ± 0.38 mg/L, which is within the acceptable limit of 10 mg/L set by USEPA (2002) [24]. The result is surprisingly low and unexpected, considering that many of the water samples were collected around towns where human activities that could cause organic pollution were very high. However, irrigation with water containing high BOD levels may lead to oxygen depletion in soil and water, which can negatively affect the growth of plants and soil microorganisms (Ashie *et al*., 2024) [7]. A high BOD is an indication of the high presence of pathogenic organisms, including aerobic bacteria, which may affect the acceptability of the vegetable for human consumption (Oshunsanya and Adeniran, 2014) [20]. On the contrary, COD concentrations ranged from 40 to 420 mg/L, with an average concentration of 154 ± 107.35 mg/L, exceeding the 20 mg/L maximum limits recommended for water bodies (Kolawole, 2011) [13]. High levels of COD in irrigation water imply the presence of pollutants and toxic substances, and when used for irrigation, crop plants may exhibit stunted growth, poor yield, and greater susceptibility to pests and diseases. The high COD values obtained in the present study suggest a likely pollution of the water used for vegetable irrigation in the sampled locations. Regrettably, as there are no limits set by WHO and many other regulating organisations for both the BOD and COD, many previous studies on irrigation water did not reckon with the parameters. Besides, bicarbonate ranged from 0.5 to 13.50 mg/L, with a mean of 5 ± 4.40, which shows that water samples from only two locations (F and H) were above the permissible limit of 10 mg/L (FAO, 2013) [8]. Under high levels of bicarbonate in irrigation water, sodium dominance in the soil may be experienced, which can ultimately result in a reduction in water infiltration rates and soil gas exchange. In addition, elevated soil pH may occur, which can cause nutrient imbalances such as iron and manganese deficiency (Sule *et al*., 2021) [22].

Further still, chloride was below the detection limit in all the water samples, while sulphate was noticed only in six (6) out of the 10 samples at greater than the 20 mg/L maximum limit in all except one. Although chloride is important for plant growth in small quantities as it plays a vital role in cell hydration and turgor maintenance in plants (Amankwa *et al*., 2023) [6], nevertheless, it enhances the total salt content (salinity) of soils. Accordingly, irrigation with water containing high amounts of chloride leads to a reduction in phosphorus availability in crop plants (Sule *et al*., 2021) [22]. Similar attributes are found with sulphate, as high levels of it in irrigation water interfere with plant uptake of some important nutrients in the soil. According to Ashie *et al*. (2024) [7], high levels of sulphate in irrigation water cause soil salinity, alkalinity, and toxicity, and irrigation with water containing excessive sulphate, may lead to reduced growth and yield, in addition to increased susceptibility to drought and pests.

Table 2: Physicochemical analysis of water samples

Parameters	Water Samples											
	A	B	C	D	E	F	G	H	I	J	Range	Mean ± SD
pH	5.70	5.40	6.00	6.50	6.70	6.20	5.96	5.88	6.73	6.09	1.33	6.12±0.41
Temperature (ºC)	28.50	28.70	28.40	28.60	28.50	27.60	27.90	27.60	27.80	27.70	1.1	28.13±0.42
Conductivity (µS/cm)	164.00	44.00	574.00	376.00	121.00	746.00	115.00	870.00	164.00	214.00	826	338.8±276.34
Turbidity (NTU)	1.70	5.70	8.70	1.50	4.30	0.30	3.50	10.20	1.60	2.80	9.9	4.03±3.10
TSS (mg/L)	0.22	0.62	0.97	0.11	0.46	0.1	0.33	1.08	0.13	0.26	0.98	0.428±0.34
TDS (mg/L)	82.00	22.00	287.00	188.00	60.50	373.00	57.50	435.00	82.00	107.00	413	169.4±138.37
Hardness (mg/L)	63.00	25.20	189.00	138.60	71.40	357.00	84.00	205.80	92.40	126.00	331.8	135.24±91.11
BOD (mg/L)	2.32	2.06	2.86	2.81	1.96	1.85	2.04	1.76	1.83	1.92	1.1	2.141±0.38
COD (mg/L)	240.00	40.00	140.00	180.00	120.00	40.00	180.00	420.00	80.00	100.00	380	154±107.35
Bicarbonate (mg/L)	1.30	0.50	7.40	5.00	1.50	13.50	1.60	12.30	3.50	3.40	13	5±4.40
Chloride (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0±0.00
Sulphate (mg/L)	84.21	ND	42.11	ND	5.26	ND	83.43	102.74	ND	36.84	102.74	35.459±38.98

3.2 Heavy Metals Presence in Water Samples

Monitoring the presence of heavy metals in irrigation water is very crucial in this kind of study, considering the fact that ingestion of the metals in any form poses a great threat to human health. Cu ranged from 0.18 to 0.34 mg/L (0.25 ± 0.07), Fe from 0.03 to 0.13 (0.11 ± 0.01) and As, from 0.01 to 0.05 (0.03 ± 0.01), and Pb, from 0.06 to 0.15 (0.10 ± 0.02). This shows the mean concentrations of heavy metals in all the water samples in the following decreasing trend: Cu > Fe > Pb > As (Table 3). Except for Cu, the concentrations of all others fell below the recommended limits for vegetable irrigation set by FAO (2013) [8]. The results further show that both Pb and As, which are almost the most hazardous of the four metals assessed, were far below their permissible limits. This may imply that the consumers of vegetables irrigated with water from the sources may not likely suffer heavy metal toxicity associated with the two metals. However, in reference to the level of safety, WHO reported that there is no known level of lead exposure that is considered safe. Moreover, despite the fact that lead is not an important element for plant growth, it can pollute soils and gradually accumulate in plants, influenced by pH and particle size (Abdallah and Mourad, 2021) [1]. On the contrary, the concentration of Fe, which is also capable of discolouring vegetable leaves and causing clogging, was very low in the water samples (Aliyu *et al*., 2017) [5]. Therefore, it may be safe to infer from the study, that heavy metal contamination of green vegetables from the various locations would be very minimal, and this can increase consumers' confidence in the quality of the vegetables being produced in the state.

Table 3: Heavy metal presence in water samples

Samples	Metals (mg/L)			
	Cu	Fe	As	Pb
A	0.21	0.10	0.02	0.13
B	0.19	0.11	0.04	0.10
C	0.34	0.12	0.01	0.15
D	0.25	0.11	0.05	0.08
E	0.29	0.10	0.01	0.09
F	0.33	0.12	0.03	0.10
G	0.35	0.11	0.02	0.11
H	0.18	0.13	0.01	0.06
I	0.18	0.09	0.04	0.09
J	0.20	0.12	0.02	0.11
Range	0.18	0.03	0.04	0.07
Mean	0.25±0.07	0.11±0.01	0.03±0.01	0.10±0.02
FAO	0.20	0.30	0.10	0.30

3.3 Microbial Loads of Water Samples

Previously, many similar studies had adopted the use of number of coliform bacteria to evaluate the microbial quality of irrigation water in order to arrive at various conclusions (Mustapha and Adeboye, 2014; Amankwah *et al*., 2023; Ashie *et al*., 2024) [16, 6, 7]. However, in the present study, as a result of greater concern with bacteria viability, we embraced the use of total viable coliform counts (TVCC) and total viable E. coli. Counts (TVEC), following Olowe *et al*. (2016) [19] and Kirianki *et al*. (2017) [12]. Results show that TVCC ranged from 6 to 22 MPN/100 ml with a mean of 14.6 ± 8.38 MPN/100 ml, indicating loadings higher than the WHO permissible limit of 1 MPN/100 ml. High TVCC loading in any water sample indicates significant faecal pollution and contamination, which further suggests potential exposure to disease infection as pathogenic organisms are likely to be present in such water samples. The results are not unexpected, given that many of the water samples were taken from locations that were close to the town, which might have exposed them to faecal contamination, especially as open defecation and grazing are still rampant in many parts of the state. Surprisingly, however, TVEC loadings fell below detectable limits. This particular result calls for further investigations, particularly with more samples collected from many more locations around peri-urban and urban towns in the state.

Table 4: Microbial loads of water samples

Sample	TVCC (MPN/100ml)	TVEC (MPN/100ml)
A	22	ND
B	16	ND
C	32	ND
D	12	ND
E	10	ND
F	12	ND
G	10	ND
H	8	ND
I	28	ND
J	6	ND

TVCC = total viable coliform counts, TVEC = total viable E-coli counts, ND = not detected

4. Conclusions

An assessment of the quality of water used for dry-season vegetable irrigation was carried out in Ondo State, Nigeria. Except for the presence of colour and taste in the water samples, and the slightly acidic pH status of a few, most physicochemical parameters (e.g., EC, TSS, TDS, BOD, etc.) were found within the permissible limits set by FAO for irrigation water. However, both total hardness and COD were higher than the recommended limits, therefore indicating the possibility of pollution and toxicity, which could be attributed to the release of domestic wastewater and solid waste into some of the water sources. Yet, most heavy metals fell within the recommended levels, thereby suggesting a clean bill of health for the water sources since ingestion of heavy metals can cause different illnesses and other health defects when taken in any form and poses the greatest danger to man. Despite the foregoing, higher values of TVCC than the recommended limit cast doubt on the integrity of the water sources. Therefore, while the present results lend credence and support to the continuous engagement of small-scale farmers in the cultivation of dry-season green vegetables, it may also go a long way in eliciting the confidence of consumers in the quality of the vegetable produced in the process. However, considering the level of total hardness and TVCC values, constant monitoring and evaluation of irrigation water quality should be taken seriously. In addition, it may be necessary for stakeholders to embark on incessant awareness campaigns against urban surface water pollution since this source appears to be the most readily available and profitable irrigation water source for farmers for dry-season vegetable farming. We further recommend the expansion of this study to cover more towns and villages in the state and, possibly for other vegetable crops, given the increasing investments in additional ones in the state.

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