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Tomato Farmers Harvest Timing Decisions in Nigeria as a Function of Agronomic and Market Factors

[version 1]

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Abstract

This study investigates the factors shaping tomato farmers' harvest maturity decisions, that is, to harvest early or wait until full ripeness. The study shows that farmers' harvest timing choices are conditioned by: (1) agronomic conditions including potential losses and varietal characteristics; and (2) market incentives, including expected prices and buyer requirements. Finding that market forces are as critical as agroecological factors, highlights the need to better align production practices with marketing systems. Investments in rural finance, storage and transport infrastructure, and market information systems could reduce post-harvest inefficiencies and support more optimal harvest timing. Regional heterogeneity in determinants of harvest maturity also points to the need for additional field-based and market-oriented research across Nigeria's diverse tomato subsector. Strengthening extension systems to integrate agronomic and market guidance, while expanding access to affordable irrigation and farmer-friendly financial cooperatives, would enhance farmers' ability to harvest and sell under more favorable conditions.

Keywords

tomato value chain, harvest maturity, market access, financial inclusion, Nigeria, post-harvest losses, regional differences, tomato farmers

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1. Introduction

Tomato (Solanum lycopersicum L.) is one of Africa's most important horticultural crops, serving as a key source of vitamins, household income, and rural employment (León-García et al., 2017). Tomato is overwhelmingly a commercial crop in Africa, grown by small and medium farmers; home-consumption of the harvest is a tiny share of output. Therefore, farmers' choices of the variety of tomato they grow, how they grow it, when they harvest it, how the farmer handles the tomato post-harvest before they sell it, and to what marketing channel they sell it are crucial decisions that affect their profits from this cash crop. The profit rate is in principal affected by: (1) the yield which is conditioned by agronomic choices given the variety; (2) the quality (size, ripeness, which is conditioned by timing of sale); (3) the loss rate from spoilage if the fruit gets too ripe or is mishandled in picking or short-term ambient storage on the farm, and packing if needed before handing off the fruit to the trader or retailer; (4) the marketing channel which conditions the price, controlling for the quality; (5) the timing of sale (when there is a glut from mass harvest volumes entering the market versus other times).

We contend that there are already emerging literatures in Africa on 1-4 but far less on 5, timing of harvest. For example, there has already been research on African tomato farming practices (Ochilo et al. 2019 for Kenya); on post-harvest on-farm losses (Alidu et al. 2016 for Ghana); and on market channel choices (e.g., Adams et al. 2021 for Ghana; and Tura and Hamo, 2018, for Ethiopia).

But there is a gap in the literature for Africa on the decision of when to harvest. Logically this would influence ripeness and ripeness plus short-term storage method would influence post-harvest loss. Ripeness, controlling for the variety, and timing of sale, can influence the market channel actors coming to buy from the farmer, and the price provided. That is of course complex: traders come to buy to transport long-distance usually would not want ripe tomatoes as they will spoil in transit; retailers and local traders might want ripe tomatoes to attract immediate customers; both would worry about tomatoes not being too ripe as they would damage easily. Moreover, season may play an important role: farmers may choose differently according to whether it is the rainy season, not as hot but with more pests, and the dry season when irrigation is used and heat is more but the market price is higher.

These practical issues have, as expected, already induced substantial research on tomato harvest timing in other regions with longer histories of growing tomatoes (for example, tomatoes have only been a major part of Nigerian cuisine for three or so decades, Liverpool-Tasie et al. forthcoming). In the US for example, Johnson et al. (2019) analyzed farmers' harvest timing decisions and effects on post-harvest loss in North Carolina. The aim of this present paper is to address the gap on the issue of the harvest timing decision for Africa, with a case study of Nigeria in two agroecological zones and in two seasons, rainy and dry.

Specifically, this study tests for the factors associated with farmers' choices of harvest timing (choice of maturity stage) in two agroecological zones of Nigeria and in rainy and dry seasons. The determinants include both agronomic/agroclimatic and socioeconomic/market factors. Besides filling a gap in the literature, insights from this analysis could be of value to inform policymakers, agricultural research and extension, and development practitioners on the design and implementation of training programs, storage and transportation investments and market development strategies.

The paper proceeds as follows. Section 2 describes the study context and sampling approach. Section 3 presents the empirical methodology. Section 4 presents result for the two study states. Section 5 discusses the findings and highlights implications.

2. Data and methods

2.1 Study area and sampling procedure

This study uses primary data collected from a sample of 800 tomato producers in two Nigerian states; Kaduna and Oyo. These two states were selected because they have substantial tomato production and represent different agroecological and socioeconomic conditions (Adelodun & Choi, 2018; NAERLS, 2022). Kaduna, in the Guinea–Sudan savanna agroecological zone, is a major supplier of tomatoes to markets nationwide. In contrast, Oyo, in the Southern Nigeria rainforest and derived savanna zones, has experienced rapid expansion in tomato production, but mainly supplies to local and regional markets. Socioeconomic conditions differ significantly between the regions: northern Nigeria has more poverty and less education on average than in the south (Otekunrin et al., 2019; Nalunga et al., 2026

A multistage sampling approach was used to collect the data used for this study. First, within each selected state, all the Local Government Areas (LGAs) were listed and two LGAs with the highest volume of tomato production were selected. LGAs are Nigeria's third administrative level of government (below the national and state governments) and equivalent to a US county.

Second, wards within the selected LGAs were listed. We then obtained the information on the volume of production in the wards from the Agricultural Development Program (ADP) office (the extension office within the LGA) and/or the director of agriculture within the chosen LGAs. We selected the top two wards (in terms of volume of tomato produced) in each of the two LGAs. This generated two wards per LGA and a total of 4 wards across the two chosen LGAs in each state.

Third, in each of the selected wards, we obtained a list of communities from Wikipedia (where available) and triangulated with information from ward key informants – LGA staff, community members such as community association leaders and those whom community members identified as with expertise. We ranked the top five communities from each ward (in terms of volume of production) and selected the top two communities from each ward. We listed all the households (doing any farming, whether of tomatoes or other) in the two selected communities in each ward.

Fourth, in the selected communities, we listed all households and farms, among which there were 2026 farmers cultivating tomatoes. We sampled 400 tomato farming households in each study state for a total sample of 800. To calculate the necessary sample size, we estimate the finite population corrected sample size for simple random survey (Lohr, 2010; Cochran, William G., 1977). We allowed for a margin of error (confidence interval) of 5% (+/-5%) and a confidence level of 95% so that the means of key outcomes lies within our confidence interval. We assume variance in responses of about 0.5 (considered to be liberal to ensure that our sample is large enough). This indicates that a sample size of 385 farmers is needed. We thus selected 400 per state to ensure we exceed the minimum sample size.

The primary respondent was the tomato plot manager. Data were collected on various socio-economic characteristics of the plot manager such as age, gender, education and marital status, and the household size, access to credit and cooperative membership. The survey also asked tomato variety used, distance to closest market, market prices, and the farmers marketing channels used (e.g. sales to wholesalers, rural aggregators, consumers etc.).

This study (MSU Study ID: STUDY00007403) received ethical approval from the Institutional Review Board of Michigan State University, and all interviews were conducted in accordance with the local legislation and institutional requirements.

Informed consent was obtained verbally from all participants after explaining and prior to survey administration. Verbal consent was chosen because many farmers had limited literacy and time constraints within the environment, making written consent impractical; however, participation was entirely voluntary.

2.2 Empirical methodology and research hypothesis

The main study variable (tomato harvest maturity stage) is a categorical variable noting whether the harvest time for farmer *i* in each production season was (1) when the tomato fruit was fully ripe and red, (2) at turning stage (when 10% to 30% of the fruit's surface shows a colour change from green to red,) or (3) at breaker stage (when the fruit shows its first blush of colour indicating that it is mature enough to ripen off the vine with full flavour and allowing for easier transport and harvesting without damage).

We adapted the model to the revealed choice set in the state. In Kaduna State, farmers either adopted at the turning stage or fully ripe stage (leading to only two possible outcomes, turning state 0, or full ripeness, 1), and thus we used a binary Probit regression model. In Oyo State, farmers picked one of the three possible options (fully ripe, breaker stage or turning stage) and thus a multinomial logit model was estimated.

In Kaduna, for the Probit,the probability of choosing full ripeness can be expressed as:

$$\Pr(y_i = 1|X_i) = \frac{\exp(X_i\beta_k)}{1 + \exp(X_i\beta_k)} \tag{1}$$

With p_i being the probability that farmer i harvests at fully ripe stage. The cumulative distribution function of a standard normal variable is represented by $\boldsymbol{\phi}$, while $\boldsymbol{X}_i'$ is a vector of k characteristics describing farmer $i's$ socioeconomic characteristics, incentives and market conditions and β represents the respective parameter estimates associated with each characteristic, representing the change in the log-odds of harvesting at full ripeness relative to harvesting at the turning stage for a one-unit increase in the explanatory variable.

In Oyo State, where farmers picked one of three possible options for their harvest period, a multinomial logit model was employed based on McFadden (1986). Farmer *i*'s representative utility (V_{ij}) is derived from harvesting at either stage j of (1) fully ripe stage (2) turning stage or at (3) breaker with j=1, 2, 3 and expressed as:

$$V_{ij} = X_i\beta_j + \varepsilon_{ij} \tag{2}$$

where X_i is a vector of all plot, farmer and market factors that affect this utility while the vector β_j represents the coefficients for the vector of explanatory variables, and ε_{ij} refers to the random errors that are assumed to be independent and identically distributed across the *j* alternatives.

The choice probability associated with each alternative harvest stage can be expressed by the following multinomial logit:

$$p_{ij} = \Pr\begin{cases} \Pr(y_i = 1|X_i) = \dfrac{1}{1 + \sum_{k=2}^{j} \exp(X_i\beta_k)} \; for\, j = 1 \\ \Pr(y_i = J|X_i) = \dfrac{\exp(X_i'\beta_j)}{1 + \sum_{k=2}^{j} \exp(X_i\beta_k)} \; \text{For j} > 1 \end{cases} \tag{3}$$

Which is the probability of farmer *i* choosing alternative *j.* where y_i is the harvest time *i* chooses. We normalize the equation by establishing the base outcome to harvesting at breaker stage and imposing the usual identifying restriction that $\beta_1 = 0$.

The associated log likelihood is thus

$$\prod_{i}^{n}\prod_{j}^{J} 1(y_i = j)\ln\Pr(y_i = j|X_i) \tag{4}$$

where $1(y_i = j)$ is the indicator of the farmers harvest time choice (equal to 1 if they selected a particular harvest time y and 0 otherwise). To maximize this log-likelihood function, we adopt the Newton-Raphson approximation method.

The study explanatory variables (that constitute vector X_i) selected were guided by theories of household production, market coordination, and post-harvest management (Barrett et al., 2001; Fafchamps and Vargas Hill, 2008; Kansiime et al., 2018; Okoye et al., 2020). We highlight five key hypotheses (See Table 1 for a summary).

The first hypothesis relates to the tomato variety. We suggest that the hypothesis is ambiguous as there is no a priori clear relation between the variety and whether the farmer needs to or wants to harvest earlier or later. Typically, tomato varietal characteristics influence the rate, perishability, and the potential market channel. Improved and hybrid varieties have been bred for: (1) uniform ripening (originally tomato varieties were "indeterminate" with harvest little by little as tomatoes ripened; in the early 1940s in California and the Soviet Union (Lukyanenko, 1991), tomatoes were bred into "determinate varieties" to accommodate large scale production of processing tomatoes that yielded an all-at-once harvest to accommodate tomato processing plants); (2) high yield; and/or (3) early maturity.

There is no clear relation between variety and timing. This is basically because traditional varieties (not bred for processing) tend to be what is called "indeterminate varieties" (varieties that ripen over individual fruits at varying (not determinate) rates and thus ripen unevenly over time). A farmer may want to leave them in the field longer to allow individual fruits longer on the vine to achieve full ripeness for example to sell to the local fresh market or to have larger quantities to harvest before hiring or allocating labor for harvesting. However, the farmer may also want to harvest (some of the fruit) of the traditional variety earlier to sell to long-distance traders often do not want the fruit fully ripened as it would spoil en route. Thus a traditional variety can be harvested early or late depending on the farmer's marketing goal. It is also possible that the farmer is using an improved variety that is not for processing but for the fresh market. That variety might be a determinate one or a non-determinate one. It might also have greater shelf life and thus allow the farmer to harvest it more ripe for a higher price but bought by a long-distance trader who wants a riper fruit for the destination market but also one that will not spoil en route.

To further complicate the timing link with the indeterminate varieties, a farmer may choose to harvest the whole plot at once even though say half of the fruit are greenish and the other half are fully ripe. This is common in situations where a

Table 1. Key hypotheses related to farmers' harvest stage decision (Expected direction).

Variable	Early harvest (Breaker or Turning stage)	Late harvest (Full ripe stage)
Variety		
Improved	±	±
Hybrid	±	±
Financial flexibility		
Non-farm income/capita	**-**	**+**
ROSCA	**-**	**+**
Market access		
Distance from farm to market	**+**	**-**
Farming season		
Wet season	+	-
Dry season	-	+
Assets		
Total cultivated area	**+**	**-**
Number of harvests in production cycle	**+**	**-**
Hired labour for harvesting	**?**	**?**
Irrigation	**-**	**+**
Market channels		
Rural aggregator/ village trader	**+**	**-**
Broker/ wholesalers	**+**	**-**
Farmers characteristics		
Age	?	?
Gender (Female)	?	?
Farming experience	?	?
Household size	?	?
Location		
LGA	±	±

traditional wholesaler comes and says that they will give a price in "bulk" to fill their truck from the field with mixed ripeness fruits and then the trader goes to sort afterwards, extracting the differences in price over the fruits according to the quality measured in ripeness. In situations where the local market is more developed and there is more competition among traders, the farmers can sort and sell by differentiated quality and get better prices for riper or larger fruit. By contrast, improved varieties as noted above, if improved to supply to the processing market, tend to be "determinate" and thus all the fruit are ready at one time to be harvested. The timing may then be chosen not by the farmer but by the processors. If the latter want to buy the fruit very ripe for high sugar content they can ask for it to be harvested late; if they want it a little greener in order to store it and stagger processing with other loads, they may ask an area to harvest a little earlier. We distinguish between hybrid and improved varieties for two reasons. First, while both offer higher yields, they possess distinct technical features: hybrid tomatoes provide superior vigor, trait uniformity, and early maturity, but require annual seed purchases. In contrast, improved varieties often offer specific disease resistance and allow for seed recycling. Separating these categories enables us to determine if harvesting practices differ across these non-traditional varieties. Second, because a farmer's choice of variety is often determined by their target market channel, controlling for this choice isolates the 'variety effect' and allows us to more accurately measure how market preferences influence harvesting decisions.

The second hypothesis examines how financial flexibility shapes harvest decisions. Farmers with non-farm income or membership in rotating savings and credit associations (ROSCA) potentially have cash sources that are not as fixed in timing as cash from the tomato harvest. They could allow the farmer to wait to sell because they are a cushion of cash. The latter allows the farmer to wait and sell later and get better prices.

The third hypothesis relates to market access and market, which is a combination of the location of the farm and the types of market channels the farmer is facing. The farmer's choice of harvest timing in this regard is conditioned by their own selling in the market, versus their selling at farmgate to rural aggregators or brokers/wholesalers. The latter is far more common in Nigeria than the former. In that case, the decision is actually the traders' of what degree of ripeness they want. If the trader intends to sell far away, they may want less ripe to endure the long trip. If they are selling closer, then they want riper to sell fast and get a better price. The farmer's choice of timing then depends on what kinds of traders they most often face.

Furthermore, the relation of the buyer type and the harvest timing may vary by state. In Kaduna (a net surplus tomato state and national supplier of tomato) farmers are more likely to face long distance traders who want the tomato less ripe as we note above. Oyo state is a net importer of tomatoes serving local and regional demand (in the south west) is strong and so farmers may be more likely to be faced by local traders and retailers who want the tomato riper and in large quantities.

Moreover, there may be a correlation between being closer to the highway and their attracting long-distance traders to come buy as it is easy to get to them, so they would harvest earlier to please that kind of trader. If they are very near a town market or far away from the road, they may want to harvest riper to please the local short-distance traders.

The fourth hypothesis is the relation of timing and season. The rainy season poses more risks for leaving fruit to ripen longer both because of rain knocking off near-ripe fruit but also because there are most pests in the rainy season. Farmers may be less willing to harvest later or if they do, they must combine it with more pesticide use. All else equal it would be more practicable to harvest later in the dry season.

Moreover, farms with irrigation may harvest later because they have water to continue cropping after the rains pass; and also, by definition are more likely to be able to farm in the dry season.

The fifth hypothesis concerns harvest timing and farm scale. Staggering harvesting across plots allows workload management especially on larger farms; thus, it may be that larger farms harvest some plots earlier while smaller farms may have the small area harvested later to maximize the return.

In all estimations, we control for farmer age, gender, experience and the local government area (LGA) farmers are located in to control for other farmer and location characteristics that might also affect their market orientation and production constraints.

3. Study results

3.1 Descriptive statistics of the study sample

Table 2 presents the distribution of farmers' chosen harvest maturity stage across the study states. The main finding is that majority of tomato farmers in the two study states harvest their tomatoes when they are fully ripe. In Oyo State, 81% of farmers harvest tomatoes at the full ripe stage, followed by 15% at the turning stage and 4% at the breaker stage. This correlates with our hypothesis above that the South farmers would harvest later probably because of a large local market and less need to harvest early to accommodate long-range traders' need for less ripe fruit.

However, the Kaduna results are similar to Oyo's: 80% of farmers harvest at the full ripe stage (80%), with the share harvesting at the turning stage (20%) barely above the share in Oyo. This is contrary to our hypothesis that the state results would be very different due to the North supplying more to long-distance trade.

Table 2. Distribution of tomato farmers harvesting at different harvest stages (outcome variable).

Maturity stage of tomato	Pooled	Kaduna	Oyo
Full ripe stage	80.5	80.2	80.6
Turning stage	17.4	19.8	15.2
Breaker stage	2.1	-	4.2
Total	100	100	100
Number of observations	781	399	382

Source: Author's estimation.

Table 3. Descriptive statistics of explanatory variables.

	Pooled		Kaduna		Oyo	
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Plot manager's age (years)	44	13.64	39	11.95	48	14.02
Plot manager is ROSCAs member (prop.)	0.37	0.48	0.16	0.37	0.58	0.49
Plot manager is male (prop.)	0.85	0.36	0.98	0.14	0.71	0.45
Hybrid variety (1/0)	0.06	0.24	0.1	0.3	0.02	0.15
Local variety (1/0)	0.57	0.5	0.28	0.45	0.85	0.36
Improved variety (1/0)	0.37	0.48	0.62	0.49	0.13	0.33
Sold to rural aggregator/village trader (1/0)	0.44	0.5	0.53	0.5	0.35	0.48
Sold to broker or wholesaler (1/0)	0.59	0.49	0.52	0.5	0.65	0.48
Sold to retailers and others (1/0)	0.13	0.34	0.14	0.35	0.12	0.33
Farming experience (years)	12	8.91	10	8.06	13	9.53
Dry season farming only	0.28	0.45	0.54	0.5	0.02	0.15
Wet season farming only	0.58	0.5	0.34	0.47	0.81	0.39
Wet and dry season farming	0.15	0.35	0.12	0.33	0.17	0.37
Ikara (Kaduna)/ Ibarapa East (Oyo) Local Government (1/0)	0.2	0.4	0.41	0.49	0	0
Kubau (Kaduna) /Orire (Oyo) Local Government (1/0)	0.3	0.46	0.59	0.49	0	0
Hired labourers on the farm (1/0)	0.87	0.34	0.8	0.4	0.93	0.26
Number of harvests in last production cycle	4.78	2.55	4.99	1.8	4.56	3.12
Price for sale per kg	254	459.86	263	455.55	244	464.79
Total tomato cultivated area	1.36	2.1	0.96	1.38	1.76	2.57
Distance to nearest market (km)	13	65.05	11	72.75	15	55.88
Household has nonfarm income (1/0)	0.39	0.49	0.56	0.5	0.21	0.41
Household used irrigation (1/0)	0.26	0.44	0.45	0.5	0.06	0.24
Household size	6	3.46	7	3.82	5	2.32

Source: Author's estimation.

Table 3 presents the summary statistics of the explanatory variables for tomato farmers in the two study states. Household heads are middle-aged in both states. More tomato farmers are male in the North: 98% in Kaduna compared with 70% in Oyo 70%. This suggests that tomato production is generally male-dominated but with higher female participation in Oyo (30%).

Membership in Rotating Savings and Credit Associations (ROSCAs) differed sharply between the two states: only 16% in Kaduna versus 58% in Oyo. In both states farmers have about one decade of experience.

There were marked differences in the types of tomato varieties cultivated. In Kaduna, 62% of farmers planted improved varieties, followed by local varieties (28%) and 10% planted hybrid varieties. In contrast, 85% of Oyo farmers cultivated local varieties, with limited adoption of improved (13%) and 2% for hybrids.

The market channel findings are surprising. In Kaduna, 53% of farmers sold to rural aggregators or village traders and 52% to brokers or wholesalers coming from outside the village. Only 14% sold direct to retailers, consumers or food vendors. In Oyo, however, a higher proportion (65%) sold to brokers or wholesalers from outside the community, while 35% relied on rural aggregators, and 10% sold to retailers, consumers or food vendors. These findings though initially surprising since Oyo farmers operate in a net tomato importing state likely reflects the high tomato demand in the more affluent southwest region that extends to urban cities in the state and neighboring states such as Lagos. It might also explain why Oyo results are similar to Kaduna as farmers are not mainly selling to just local buyers.

About half of Kaduna farmers cultivated tomatoes in both seasons but a surprisingly high share grows tomatoes only in the dry season. In contrast, 81% of Oyo farmers cultivated during the wet season only, with only 17% farming in both the wet and dry season. This is because Kaduna has a strong irrigation system (linked to investments in rice irrigation schemes) while Oyo farmers almost exclusively depend on rainfall. Irrigation use differs sharply across regions, with 45% of farmers using some form of irrigation in Kaduna compared to only 6% in Oyo.

Average household tomato cultivated area was just under 1 hectare in Kaduna and 1.8 hectares in Oyo. Surprisingly, the average price of tomato is very close between the states. The price per kilogram of tomatoes was 263 naira in Kaduna and 244 in Oyo.

In both states a large share of farmers use hired labor: 80% in Kaduna and more than 90% in Oyo. Again surprisingly, the distance to closest market was similar in Oyo (15 km) and Kaduna (11 km). These are very short distances so it shows farmers are not faced with a challenge of remoteness.

Again surprisingly, nonfarm employment was far higher in the North (56% of Kaduna farmers) compared with Oyo (21%). This is opposite to what we expected from the more urbanized South and very interesting.

3.2 Factors influencing harvest maturity stage decision among farmers in Kaduna State

Given that the state-level patterns are surprisingly similar between Kaduna and Oyo, there is considerably more interest in understanding inter-farm variations per state. Table 4 presents the results identifying the determinants influencing farmers' decision to harvest tomatoes at the full ripe stage relative to the turning stage in Kaduna State. Three key findings stand out.

First, growing a hybrid variety reduced the probability (relative to local varieties) of a farmer harvesting at the full ripe stage. This aligns with our hypothesis explained above.

Second, the plot manager being male reduces the likelihood (compared to females) of harvesting at full ripeness. This might reflect male farmers tending to sell to long-distance traders versus females selling to local traders and retailers.

Third, larger households tend to harvest at full ripeness compared with smaller households. This may be due to labor availability for supervision or direct labor, although recall that the great majority of farms hire labour.

3.3 Determinants of Tomato Harvest Maturity Stage decisions in Oyo State

Table 5 presents the Oyo results. Identifying the determinants influencing farmers' decision to harvest tomatoes at the full ripe and turning stages relative to the breaker stage in Oyo State. Five key findings were observed.

First, Contrary to Kaduna, using a hybrid was associated with harvesting at both the full ripe and turning stages. Planting improved varieties is also correlated with harvesting later. The positive effects of modern varieties in Oyo might reflect the ready market for fully ripe tomatoes in a region of excess tomato demand.

Second, Farmers selling to rural aggregators or village traders, were more likely to harvest at full ripe and turning stages relative to the breaker stage. These effects are large. This goes along with our hypothesis that local sales are more likely to be of ripe fruit, versus long distance traders.

Third, farmers who use irrigation are much more likely to harvest at turning or full-ripe stages than at breaker stage. This aligns with the expectation that irrigation reduces production risk and allows farmers to maintain crops longer in the field. Interestingly, and in contrast with Kaduna, farmers who were members of rotating savings and credit associations and had non-farm income were less likely to harvest at later maturity stages relative to the breaker stage. This contrasts with our hypothesis. It is possible farmers sell earlier to pay back the ROSCA. It is also possible that having outside cash allows the farmers to produce more and sell to the long-distance traders who want greener fruit.

Fifth, the number of harvests in the last production cycle was positive and significant for harvesting at the turning stage. This is consistent with the study hypothesis that the number of harvests increases the likelihood of harvesting at the turning stage, as farmers who harvest more frequently tend to pick fruits at earlier maturity stages to reduce losses and manage their output supply over time.

Table 4. Factors associated with farmer's harvest time decision in Kaduna state.

Variables	Full ripe stage
	Base = turning stage
Improved variety (base Local variety)	0.036
	-0.371
Hybrid variety (base Local variety)	-1.539***
	-0.454
Total cultivated area (ha)	0.16
	-0.206
Total cultivated area squared (ha^2)	-0.014
	-0.011
Plot manager's gender (1=all male)	-13.307***
	-0.62
Sell to rural aggregator/village trader	-0.6
	-0.391
Sell to broker or wholesaler (base retailers, food vendors and others)	-0.549
	-0.378
Farming season (1=wet season only, base dry season and wet and dry season)	-0.628*
	-0.362
Age of plot manager	-0.003
	-0.013
Distance from farm to market (km)	0.002
	-0.001
Ikara Local Government (1/0)	-0.569**
	-0.285
Hired laborers (1=yes)	-0.534
	-0.372
Household size (number)	-0.073*
	-0.042
Rainfall dependent (1=no irrigation)	0.341
	-0.365
Has non-farm income	0.326
	-0.272
Farming experience (years)	-0.022
	-0.017
Plot manager is member of ROSCA	0.294
	-0.388
Number of harvests in last production cycle (number)	-0.01
	-0.08
Constant	16.832***
	-1.12
Observations	397

Source: Author's estimation. Robust standard errors in parentheses,
***p < 0.01,
**p < 0.05,
*p < 0.1.

Table 5. Factors associated with farmer's harvest time decision in Oyo state.

Variables	Full ripe stage turning stage base = breaker stage	
Improved variety (base Local variety)	2.090*	0.11
	-1.226	-1.2
Hybrid variety (base Local variety)	15.367***	14.651***
	-1.445	-0.763
Total cultivated area (ha)	0.909**	0.693*
	-0.39	-0.358
Total cultivated area squared (ha^2)	-0.041**	-0.028**
	-0.016	-0.014
Plot manager's gender (1=male)	-0.649	-1.025
	-0.944	-0.849
Sell to rural aggregator/village trader	1.944**	1.239**
	-0.787	-0.602
Sell to broker or wholesaler (base retailers and others)	0.349	0.133
	-0.78	-0.567
Farming season (1=wet season only, base dry season and wet and dry season)	-0.252	-0.132
	-0.861	-0.773
Age of plot manager	-0.059	-0.036
	-0.037	-0.033
Distance from farm to market (km)	0.048	0.056
	-0.058	-0.055
Hired laborers (1=yes)	-1.974	-1.068
	-1.839	-1.703
Household size (number)	-0.192	-0.107
	-0.152	-0.134
Rainfall dependent (1=No irrigation)	-14.827***	-13.869***
	-1.308	-1.095
Has non-farm income	-1.735**	-1.826***
	-0.766	-0.677
Farming experience (years)	0.042	0.006
	-0.058	-0.054
Plot manager is member of ROSCA	-1.368*	-0.756
	-0.772	-0.728
Number of harvests in last production cycle (number)	0.042	0.214*
	-0.126	-0.114
Constant	20.228***	19.395***
	-3.829	-3.613
Observations	347	347

Source: Author estimations:
***p < 0.01,
**p < 0.05,
*p < 0.1. The LGA dummy drops due to collinearity.

4. Discussion, conclusion and policy implications

The study concludes that tomato farmers' harvest maturity decisions are shaped by a combination of economic and agronomic factors, reflecting a strategic balance between minimizing losses, maximizing returns, and meeting market requirements. There are several surprising findings in the study.

First, despite the difference in the study regions, with one being surplus and the other tomato-deficit, the patterns were very close in terms of the share of farmers selling fully ripe around 80%.

Second, inter-farm patterns in the determinants of tomato harvest time emerged between the states. But the similarities of effects were as surprising and often more interesting than the differences.

First, there was a difference between the states in the effect of ROSCA membership and non-farm employment. In Kaduna, participation in ROSCA was positively associated with delayed harvesting, suggesting that access to savings enhances farmers' financial flexibility, allowing them to wait for full ripeness before selling, which reflects cash timing effect. Conversely, in Oyo, ROSCA membership was associated with earlier harvesting, possibly due to correlation with trader type, or perhaps cash needs to pay back credit. Similarly, non-farm income promoted earlier harvesting in Oyo, as financially diversified farmers may be less dependent on immediate sales and proximate markets and thus more likely to sell to harvest early to allow for broader market access than those without such flexibility.

Second, the impact of market channel was more pronounced role in Oyo State, where selling to rural aggregators (compared to those selling to retailers) appears to push farmers toward stages that align with transport and market readiness, in a high-demand context where tomato sales are quite rapid. In contrast, in Kaduna, biophysical and varietal factors, such as improved varieties and production conditions, were more influential, reflecting the region's stronger production orientation.

Overall, the findings support a contextualized understanding of tomato harvest maturity: in high-supply, production-oriented zones such as Kaduna, agronomic and varietal factors, along with distance to markets, dominate, while in high-demand (net importing) zones such as Oyo, institutional and financial dynamics play a greater role. A key finding from this study is that harvest maturity decisions are not purely agronomic but rather the outcome of a complex interaction among agronomy, financial capacity, and market structures.

These findings highlight the importance for government, donors, agronomists and development practitioners to recognize that market factors are as critical as agroecological factors in determining when farmers choose to harvest.

Given regional differences in the determinants of harvest maturity, donors, development practitioners and policymakers should support further field-based and market-oriented research to understand how variety characteristics, financial access, and intermediary structures interact across Nigeria's rapidly expanding and geographically diverse tomato subsector. Evidence from such research would guide the design of region-specific agricultural financing, extension and training programs, and post-harvest infrastructure programs that reflect local realities.

Strengthening extension systems to provide integrated agronomic and market-oriented advice, particularly on how different varieties perform across harvest stages and markets, would help farmers align production decisions with buyer preferences and reduce post-harvest losses. In addition to investments in infrastructure, our findings suggest that expanding access to affordable irrigation technologies is equally critical, as irrigation availability allows farmers to delay harvesting. The study findings also call for continued efforts to strengthen and expand financial cooperatives and agricultural microcredit programs. Expanding these mechanisms to mirror and augment the current benefits of ROSCA participation will enable farmers to access flexible financing that allows them to harvest and sell their produce under more favorable market conditions.

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