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# How are the production practices of vegetable farmers in Odisha transforming?

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## *Key Findings*

Agricultural transformation and smallholder commercialization are accompanied and driven by deepening integration of farmers into input markets and associated technological change. This project note examines two related questions: (1) How do households enter commercial vegetable cultivation? (2) How have technologies used to produce vegetables changed over time? The following key findings stand out:

- **Vegetable farming in Odisha is a long-standing activity.** Most farmers entered vegetable cultivation over 20 years ago, with expansion accelerating 20–30 years back as markets deepened. Fewer than one in five respondents are first-generation vegetable farmers.

- **Entry into vegetable farming is primarily self-financed.** Over 80% of farmers required startup capital to purchase inputs or make plot modifications such as land levelling. These investments were funded mainly through agricultural earnings, migration income, or non-farm earnings. Self-help groups are also an important source of finance for these investments.

- **Subsistence coexists with commercialization.** Most farmers were partly motivated to start producing vegetables for home consumption, but virtually all sell some of what they produce. Marketed surpluses of vegetables have risen gradually, to reach over 70% by 2025, without displacing household self-provisioning, and own production accounts for around half of farmers' vegetable consumption.

- **Crop portfolios are both concentrated and diverse.** Production is dominated by a small set of "commodity vegetables" (most importantly tomato and brinjal), alongside a wide array of niche crops grown by smaller numbers of farmers.

- **Recent contraction in crop diversity and off-season production signals rising climate stress.** The share of household growing vegetables in multiple seasons, and the number of

crops produced per farm has fallen slightly, consistent with increasing climate stress and perhaps reflecting competitive pressures from out of state vegetable producers.

- **Adoption of productivity enhancing agricultural technologies is at a transitional stage.** Hybrid vegetable seed, inorganic fertilizers, pesticides, and mechanized land preparation are widely adopted, but adoption of more advanced technologies that could give rise to greater commoditization (e.g. seed trays, seedlings purchased from nurseries, plastic mulch, drip irrigation, drones) remains low. Adoption of environmentally friendly inputs such as vermicompost, organic pesticides, and insect traps is limited.

- **Technology adoption is shaped by clustering and scale.** Uptake of inputs, mechanization, and post-harvest handling tends to be greater in areas with high concentrations of vegetable production and among larger farms, reflecting agglomeration effects and access to service markets.

- **Expansion of irrigation access has been a critical catalyst for smallholder vegetable commercialization**. The number of irrigated parcels of land operated by surveyed households has grown 74 percent since 1980, with irrigation accelerating sharply after 2010. Improving access to irrigation post-2010 has spurred entry into vegetable cultivation and simultaneous adoption of a complementary bundle of productivity enhancing technologies.

- **Vegetable cultivation relies heavily on private investments in irrigation**, particularly open wells and borewells. Government irrigation schemes have been targeted primarily toward rice. Although more than half of irrigated parcels of land are served by government irrigation and the number of parcels with access to government irrigation has grown 35 percent in the past 15 years, the expansion of private irrigation provision has been almost twice as fast, growing 67 percent in the same period.

## Entry into vegetable farming

Table 1 presents information on the history of entry into vegetable farming by surveyed households. Although vegetable farmers' average age is 48, the average age at which farmers first started cultivating vegetables is 24, indicating that most vegetable farmers have been practiced in the activity for more than two decades. Only 19 percent of respondents are first generation vegetable farmers, originating from households in which no parent had ever cultivated vegetables. Close to half are second generation, indicating that vegetable cultivation was initiated by their parents and 27 percent are from families that have farmed vegetables for longer than the respondent can recall. This pattern suggests that vegetable cultivation has been present in Odisha for a long time but started to expand 20-30 years ago as commercialization increased.

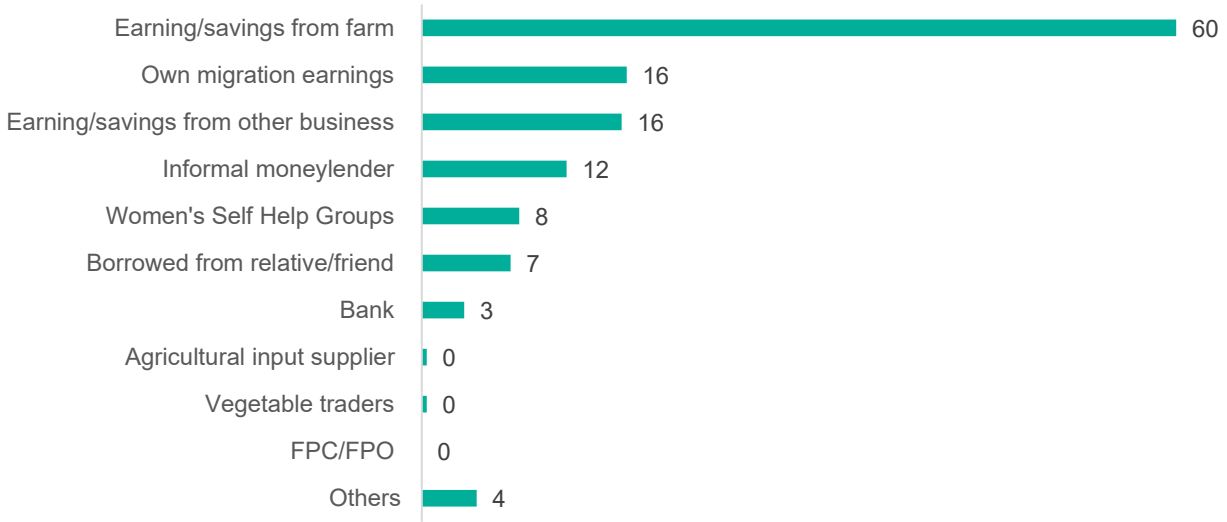
Entry into vegetable cultivation required a capital investment for 81 percent of respondents, averaging ₹24,129 ($277) at constant 2025 prices. The main source of investment for entry into vegetable cultivation is earnings or savings from own farm, underlining diversification of existing agricultural activities as the main pathway into commercial vegetable production. Notably, earnings from own migration, and earnings from non-farm business each funded entry into vegetable farming for 16 percent of respondents, highlighting important linkages between off-farm employment and agricultural commercialization. Informal money lenders and women's self help groups (WSHG) were a source of funds for 12 percent

and 8 percent of respondents respectively, the latter suggesting that credit from WSHGs can play a catalytic role in agricultural diversification. Banks supplied funds used in only 3 percent of cases, and farmer producer organizations or companies (FPOs and FPCs) none. Agricultural input suppliers and vegetable traders also play a negligible role in financing entry into vegetable farming (less than 1 percent each) (Figure 1).

**Table 1:** Characteristics of entry into vegetable cultivation (percentage of vegetable farming households reporting)

| Item | Vegetable farmers |
|---|---|
| **Respondent's age at first entry into veg farming (years)** | 24.2 |
| **First generation vegetable farmer (%)** | 18.9 |
| **Second generation vegetable farmer (%)** | 45.9 |
| **Third generation vegetable farmer (%)** | 8.7 |
| **Family has farmed vegetables longer than respondent can remember (%)** | 26.6 |
| **Required any capital to begin vegetable farming (%)** | 81.2 |
| **Value of startup capital for vegetable farming (INR, constant 2025 prices)** | 24,129 |
| **Received any assistance to begin vegetable farming (%)** | 3.5 |
| **Area of vegetable land cultivated expanded in the past 10 years (%)** | 44.3 |
| **Area of vegetable land cultivated remained the same in the past 10 years (%)** | 36.2 |
| **Area of vegetable land cultivated contracted in the past 10 years (%)** | 19.5 |

**Figure 1:** Sources of capital used to fund in entry into vegetable farming (percentage of households reporting)



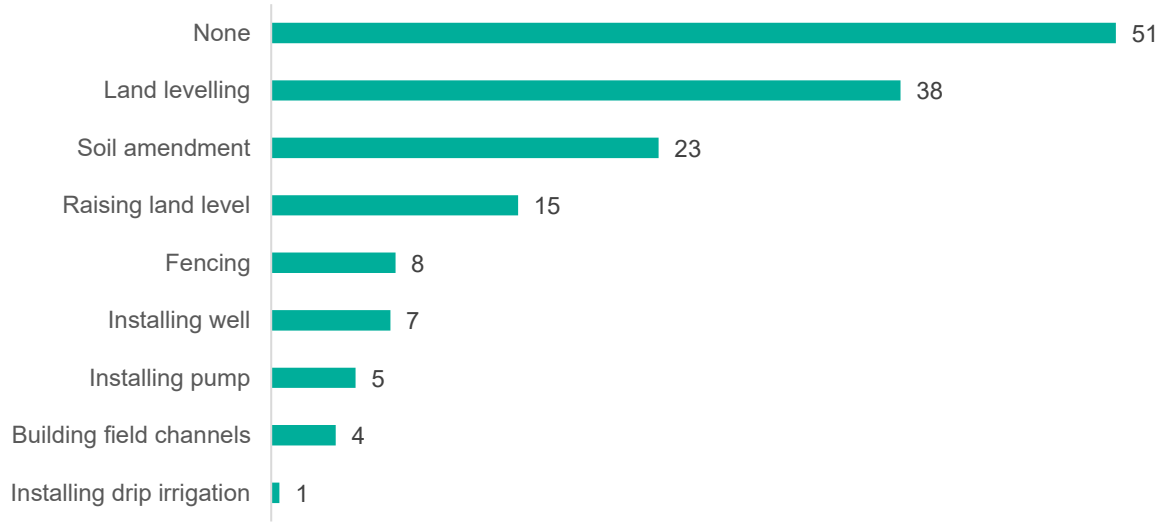

Source: INCATA Odisha Farmer Survey 2025

Half of respondents made no changes to their land when initiating vegetable cultivation, but 38 percent leveled land and 15 percent raised the level of their land, likely requiring significant investment of time and/or resources, while 23 percent practiced soil amendment. Investments related to irrigation are also common, with 7, 5, 4 and 1 percent of respondents, respectively, digging wells, installing pumps, and digging field channels, and installing drip irrigation, reflecting the importance of irrigation for enabling commercial vegetable production (Figure 2).

Only 4% of households reported receiving external assistance to initiate vegetable farming, primarily from WSHGs, or producer groups under the Government of Odisha's Agricultural Production Cluster (APC) program (each mentioned by about one third of respondents, conditional on receiving assistance). Smaller numbers of respondents (17% each, conditional on receiving assistance) reported receiving assistance from government subsidy programs and agricultural extension officers. These figures suggest that while programs such as these can play an important role in assisting some farmers, spontaneous entry into vegetable farming without any external source of directed assistance is the norm.

Forty-four percent of respondents who had farmed vegetables for at least 10 years had expanded the areas under vegetable cultivation within the past ten years, while 36 percent had made no change, and 20 percent had contracted, indicating a tendency for entrants into vegetable farming to subsequently increase the scale of production, suggesting that vegetable cultivation is often a rewarding activity.

**Figure 2:** Changes made to agricultural land operated to initiate vegetable farming (percentage of households reporting)

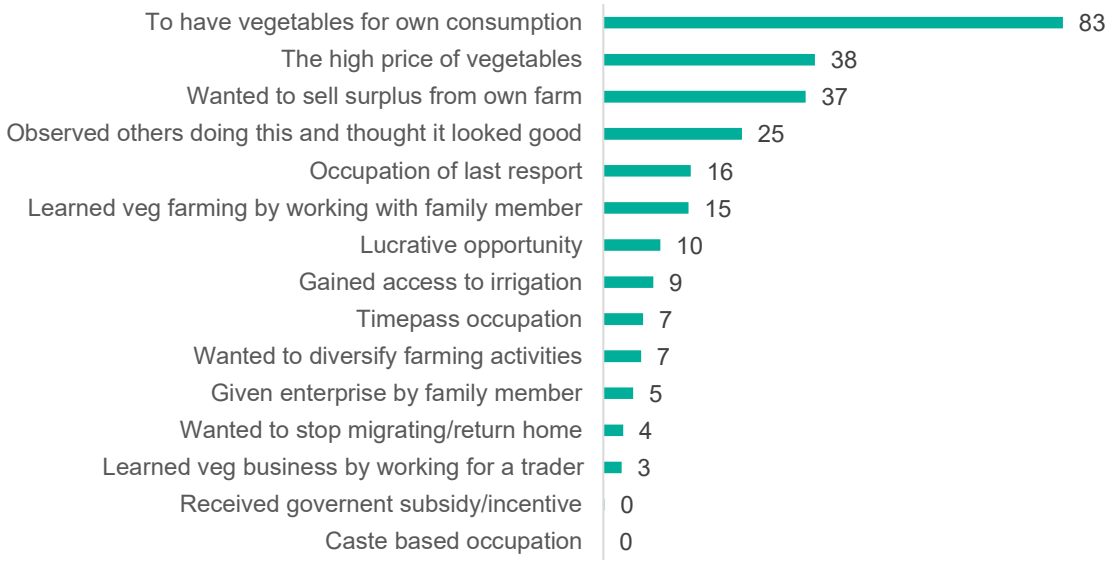



Source: INCATA Odisha Farmer Survey 2025

Figure 3 presents the motivations of vegetable farmers for initiating production. By far the most common stated motivation was to produce vegetables for own consumption, suggesting that a progression from subsistence to more commercially oriented production occurred over time (as 99 percent of respondents sold at least some of the vegetables they produced in the year prior to the survey). At the same time several responses reveal commercial motivations, indicating that subsistence and income objectives are not mutually exclusive. Thirty-eight percent of respondents referred to the high price of

vegetables, 37 percent mentioned wanting to produce a surplus for sale, 10 percent perceived vegetable farming as a lucrative opportunity, and 7 percent wanted to diversify farming activities.

**Figure 3:** Motivations for entry into vegetable cultivation (percentage of households reporting)




Source: **INCATA Odisha Farmer Survey 2025**

Observing others farming vegetables successfully motivated 25 percent of respondents to begin doing so themselves, highlighting the importance of the demonstration effect produced by other farmers, while 15 percent were motivated by learning from a family member and 5 percent by being handed the activity by a family members, indicating the importance of within family transmission of farming practices. Nine percent citied gaining access to irrigation as a motivation, underlining its role as a catalyst for vegetable farming. Sixteen percent and seven percent of respondents, respectively, reported entering vegetable farming as an occupation of last resort or a ‘timepass’ occupation, perhaps suggesting that some underemployed educated rural youth may take up vegetable farming because of a lack of non-farm work options. No respondents reported vegetable farming as being a caste-based occupation, suggesting a degree of inclusivity, and none was motivated to start by receipt of a government subsidy or incentive.

## Sequence of vegetable cultivation commercialization

Table 2 presents the evolution of vegetable farming characteristics over time, by season, share of production sold (marketed surplus) and share of household vegetable consumption originating from own production. We restrict the sample to households that have produced vegetables for more than 10 years to produce a quasi-panel, for the first year of vegetable cultivation (which varies by household), 2015 and 2025. The post-monsoon cool season is peak season for vegetable production. The share of vegetable farming households growing vegetables in cool season increased slightly from first year of vegetable production (79 percent) to 2025 (83 percent), possibly indicative of improving irrigation access, as growing vegetables in cool season often requires irrigation. The share of households growing vegetables in rainy season increased marginally from first year of cultivation (59 percent) to 2015 (61

percent), but fell slightly in 2025 (56 percent). The pre-monsoon hot season is least favorable for vegetable cultivation and most dependent on irrigation access, and follows a similar pattern to rainy season cultivation, rising from 21 percent in first year of cultivation to 24 percent in 2015, but dropping slightly in 2025 to 23 percent.

The share of households farming vegetables in 1, 2, or 3 seasons follows a similar trend. Fifty-seven percent of households grew vegetables in only one season when starting, falling slightly to 51 percent in 2015, before rising slightly to 53 percent in 2025. Conversely, the shares of households growing vegetables in 2 and 3 seasons increased slightly from year of first production to 2015 but decreased marginally by 2025.

The overall pattern evident is one of limited overall change in the number of growing seasons, indicating that vegetable farming has grown at the extensive margin (by bringing land not previously used to produce vegetables under cultivation), rather than at the intensive margin (by increasing the number of annual cycles of vegetable production). However, although variation between years in the number of growing seasons is small and must be interpreted with caution, the direction of the trends consistently points to a slight decline in off-season vegetable cultivation post 2015. We interpret them to suggest that rainy season and hot season vegetable cultivation may have faced increasing challenges due to climate stress over the past decade. This impression is consistent with observations during fieldwork, during which respondents in several areas reported that vegetable cultivation had declined locally due to water shortages, weather extremes, or the deterioration of irrigation systems.

**Table 2:** Seasonal vegetable farming characteristics and disposal of vegetables produced, by year

| Item | First year of vegetable cultivation | 2015 | 2025 |
|---|---|---|---|
| **Growing vegetables in cool season (%)** | 78.9 | 82.0 | 83.2 |
| **Growing vegetables in rainy season (%)** | 58.5 | 60.9 | 55.9 |
| **Growing vegetables in hot season (%)** | 21.0 | 23.6 | 22.7 |
| **Grew vegetables in one season** | 56.9 | 50.7 | 53.2 |
| **Grew vegetables in two seasons** | 27.9 | 32.1 | 31.8 |
| **Grew vegetables in three seasons** | 15.3 | 17.1 | 14.1 |
| **Marketed surplus of vegetables (%)** | 62.2 | 65.3 | 70.6 |
| **Vegetables consumed by the household that were purchased (%)** | 46.6 | 44.9 | 45.9 |

**Source:** INCATA Odisha Farmer Survey 2025. Note: sample is restricted to households that started growing vegetables before 2015

Farms' marketed surplus of vegetables increased gradually over time, from 62 percent in the first year of vegetable production to 71 percent in 2025. This finding has several implications. First, by inference, the share of vegetables that households consumed from their own production was significant (around 30-40% in all years), suggesting that commercial vegetable cultivation does not occur at the expense of self-provisioning, reflecting the high importance ascribed to production for own consumption in Figure 3. Second, the skills of vegetable producers may have increased with experience, leading to higher out-

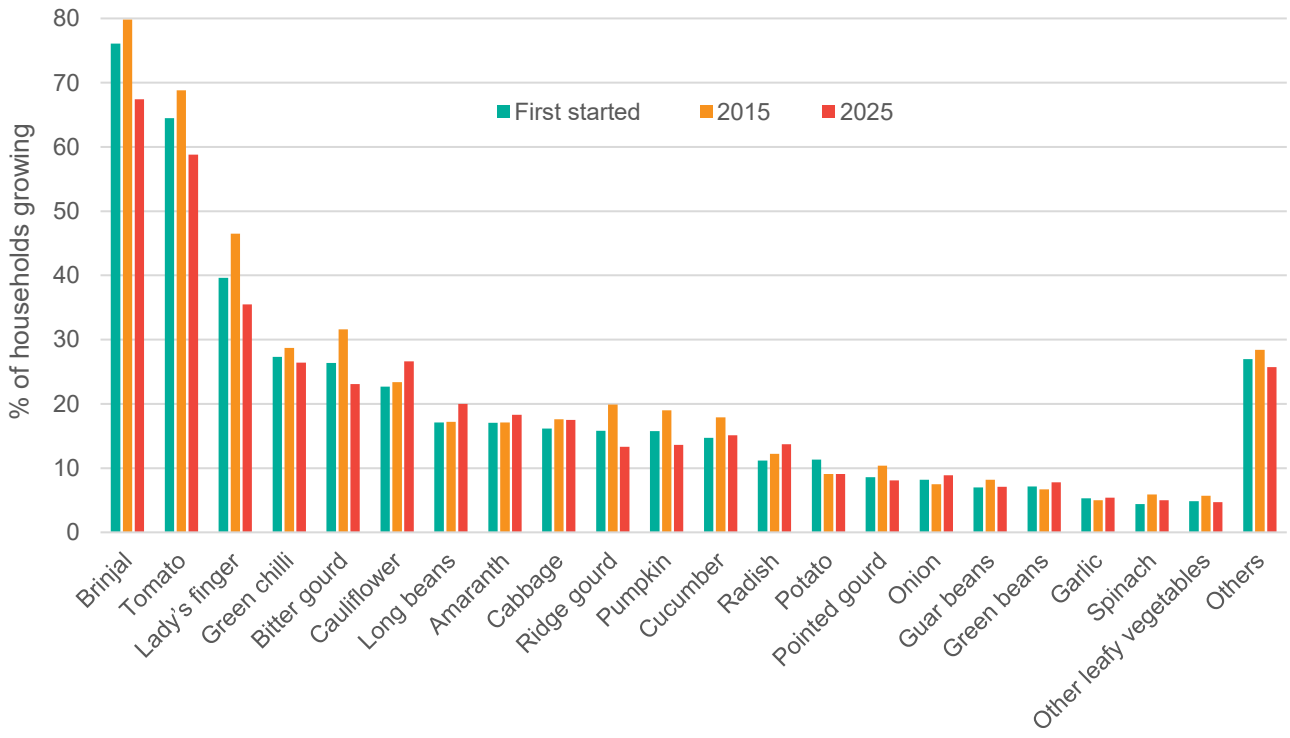
put. Third, vegetable yields may have increased with the application of production enhancing technologies, leading to larger marketed surpluses (see Figure 5). Fourth, some vegetable producers may have expanded the area under cultivation, leading to higher surpluses.

The share of vegetables consumed by households that were purchased from the market remained stable over time, at around 45 percent. This is likely to imply that households purchase types of vegetables they do not produce or buy during seasons when they do not grow vegetables.

## Crop choice

Figure 4 presents the share of households growing vegetables of different types by year, using the same quasi-panel of households who had been growing vegetables for more than a decade. Brinjal (eggplant) and tomato are by far the most widely grown vegetables, produced by 67 percent and 59 percent of households, respectively, in 2025. Ladies finger (okra) was produced by 36 percent of households and green chili, bitter gourd and cauliflower by more than 20 percent. A leafy vegetable, amaranth, was grown by 20 percent, and cabbage, ridge gourd, cucumber and radish (mooli) grown by more than 10 percent. A total of 39 vegetables, including several root crops, were reported to be grown. Thus, there is a high concentration of production in several key 'commodity vegetables', but with a high number of diverse 'niche vegetables' also grown by smaller numbers of households.

**Figure 4:** Percentage of households growing horticultural crops, by year




**Source:** INCATA Odisha Farmer Survey 2025. Note: Sample is restricted to households that started growing vegetables before 2015.

The temporal trend in the share of households producing vegetables of each type follows a similar pattern to the number of seasons in which vegetables were grown, as discussed above, increasing between the year when households first initiated vegetable farming and 2015, and declining in 2025 to levels below those in the first year of vegetable farming. For example, 76 percent of households grew tomato in their first year of production. This level increased to 80 percent in 2015, before falling to 67

percent in 2025, a decline of 13 percentage points. Among the 25 vegetables produced by 5 percent or more households, the share of households growing increased for 15 vegetables and declined for 2 between first year of growing and 2015, but increased for 5 vegetables and declined for 13 from 2015 to 2025. The only vegetables for which share of households growing increased between first year of vegetable farming and 2025, were cauliflower, long beans, amaranth, cabbage, and radish. The average number of vegetables produced per household in first year of growing vegetables was 4.5. This number rose to 4.9 in 2015, then fell to 4.3 in 2025.

We suggest two possible explanations for this pattern. First, increasing climate stress over the past decade may have pushed some households to stop growing certain vegetables in the hot season and rainy, consistent with the trends in Table 2. Second, inflows of vegetables from out of state may have eroded, or lessened incentives for, the production of certain vegetables. However, the increase in the share of households producing of a small subset of vegetables (e.g. cauliflower, cabbage) may suggest progression along the product cycle toward local cultivation on some kinds of commodity vegetables that were previously sourced from out of state.

## Technology adoption

Table 3 presents information on the share of vegetable farmers currently using a variety of technologies. Except for hybrid rice seed and hybrid maize seed, use of these technologies is reported in relation to their role in vegetable cultivation. We find the following.

First, adoption of hybrid vegetable seed is extremely widespread, reported by about 81 percent of vegetable farming households. Rates of hybrid vegetable seed use are almost identical in blocks with low and high concentrations of vegetable farms (about 80 percent in both groups), reflecting the very widespread diffusion of this technology. However, adoption is significantly higher among farms in the largest operated landholding tercile (land tercile 3, 82 percent) than among those in the smallest tercile (tercile 1, 75 percent).

Second, use of hybrid rice seed is widespread, reported by about 60 percent of vegetable farms overall. Adoption is significantly more common in high vegetable concentration blocks (60 percent) than in low concentration blocks (52 percent). The largest tercile of farms adopts hybrid rice seed at substantially higher rates (70 percent) than the smallest tercile (47 percent). A similar pattern is observed for hybrid maize seed, though adoption rates are much lower overall (5 percent), reflecting the more limited role of maize relative to rice in these farming systems.

Third, use of seed trays and purchased vegetable seedlings is very limited, adopted by about 3 percent of households each. This reflects the predominance of traditional practices of establishing seedlings in soil and the limited availability of commercial nurseries. There are no statistically significant differences in adoption rates between high and low vegetable concentration blocks, nor between farms in land tercile 1 and tercile 3.

Fourth, rates of adoption of inorganic fertilizers (DAP, urea, etc.) are high but not universal, reported by 94 percent of vegetable farms. Adoption is significantly higher ($p<0.01$) in high vegetable concentration blocks than in low concentration blocks (96 versus 89 percent). Differences by landholding tercile are small and only weakly statistically significant, suggesting that access to inorganic fertilizers is broadly scale neutral.

Fifth, use of manure as a fertilizer is also extremely common, though somewhat lower than that of inorganic fertilizers, reported by 85 percent of farms overall. There is no statistically significant difference in manure use between high and low vegetable concentration blocks, indicating similar geographic access. However, the largest third of farms are significantly more likely to use manure (90 percent) than the smallest third (82 percent).

**Table 3:** Percentage of vegetable farming households currently using agricultural technologies (whole sample, high and low vegetable farm concentration blocks, first and third operated land terciles) and tests of statistical significance

| Respondents currently using… | All vegetable farms (%) | Low con-centration block (%) | High con-centration block (%) | P-value | Land Tercile 1 (%) | Land Tercile 3 (%) | P-value |
|---|---|---|---|---|---|---|---|
| **Hybrid vegetable seed** | 80.8 | 79.8 | 80.3 | 0.845 | 75.3 | 82.4 | 0.001*** |
| **Hybrid rice seed** | 59.9 | 52.4 | 60.2 | 0.004*** | 47.2 | 70.3 | 0.000*** |
| **Hybrid maize seed** | 5.3 | 4.0 | 6.4 | 0.068* | 3.4 | 8.7 | 0.000*** |
| **Seed trays** | 2.6 | 2.1 | 2.6 | 0.563 | 2.0 | 3.4 | 0.125 |
| **Purchased vegetable seedlings** | 2.6 | 1.7 | 2.9 | 0.167 | 2.3 | 3.8 | 0.114 |
| **Inorganic fertilizers** | 94.2 | 89.4 | 96.4 | 0.000*** | 92.8 | 95.2 | 0.065* |
| **Manure** | 85.3 | 85.8 | 83.1 | 0.183 | 81.7 | 89.8 | 0.000*** |
| **Vermicompost** | 2.7 | 1.3 | 2.5 | 0.118 | 1.5 | 3.9 | 0.007*** |
| **Raised bed planting** | 31.9 | 29.1 | 34.6 | 0.034** | 32.8 | 33.1 | 0.917 |
| **Trellising** | 23.9 | 26.3 | 25.7 | 0.804 | 21.6 | 24.5 | 0.214 |
| **Plastic mulching** | 2.9 | 1.1 | 4.4 | 0.001*** | 2.1 | 3.6 | 0.104 |
| **Pesticide** | 89.5 | 80.7 | 92.7 | 0.060* | 84.4 | 92.0 | 0.178 |
| **Organic pesticide** | 5.0 | 2.8 | 6.6 | 0.000*** | 3.8 | 6.3 | 0.001*** |
| **Insect traps** | 0.6 | 0.0 | 0.7 | 0.000*** | 0.3 | 0.9 | 0.000*** |
| **Herbicide** | 27.6 | 15.9 | 34.5 | 0.002*** | 23.8 | 32.1 | 0.043** |
| **Tractor** | 67.7 | 57.3 | 72.9 | 0.000*** | 64.1 | 68.1 | 0.126 |
| **Power tiller** | 13.1 | 13.4 | 13.6 | 0.921 | 14.3 | 14.9 | 0.754 |
| **Power weeder** | 3.3 | 1.1 | 4.8 | 0.000*** | 2.0 | 5.1 | 0.002*** |
| **Drone** | 0.4 | 0.0 | 0.1 | 0.507 | 0.5 | 0.4 | 0.95 |
| **Grading/sorting vegetables** | 65.0 | 62.6 | 64.7 | 0.429 | 60.0 | 70.4 | 0.000*** |
| **Washing vegetables** | 59.7 | 57.7 | 61.1 | 0.218 | 52.3 | 66.9 | 0.000*** |
| **Crates/trays** | 21.8 | 20.2 | 20.1 | 0.979 | 13.2 | 30.2 | 0.000*** |
| **Plastic bags/bagging** | 31.0 | 20.0 | 30.7 | 0.000*** | 23.8 | 39.1 | 0.000*** |

**Source:** INCATA Odisha Farmer Survey 2025. Note: *** p<0.01, ** p<0.05, * p<0.10

Sixth, use of vermicompost - often promoted by NGOs and government agencies as an alternative to inorganic fertilizers - remains limited, reported by about 3 percent of farms. Adoption does not differ significantly between high and low vegetable concentration blocks but is significantly higher among farms in land tercile 3 than among those in land tercile 1.

Seventh, raised bed planting and trellising are agronomic practices that can increase the productivity and quality of gourds and other vines by raising them off the ground and exposing them to the light. About 32 percent of farms report using raised bed planting, while 24 percent use trellising, often in tandem, suggesting widespread uptake among households who grow gourds and other climbing plants (these account for 39 percent of vegetable farms). Raised bed planting is significantly more common in high vegetable concentration blocks than low, but with no significant difference by farm size. Trellising does not differ significantly across vegetable concentration blocks or landholding terciles.

Eighth, plastic mulching, used primarily for weed control and moisture retention, is adopted by only about 3 percent of vegetable farms. Use is significantly more common in high vegetable concentration blocks than in low concentration blocks but does not vary significantly by landholding tercile.

Ninth, pesticide use is extremely widespread, practiced by nearly 90 percent of vegetable farmers. Adoption rates are higher in high vegetable concentration blocks than in low concentration blocks, though this difference is only weakly statistically significant. Differences by landholding tercile are not statistically significant. The widespread use of pesticides reflects the vulnerability of vegetable crops to pest attack but has potentially important implications for human and environmental health.

Tenth, organic pesticides such as neem oil, promoted as alternatives to highly toxic synthetic pesticides, are used by about 5 percent of vegetable farmers. Adoption is significantly higher in high vegetable concentration blocks and among larger farms. Insect traps - an alternative pest management strategy - are used by fewer than 1 percent of farms. Their use is concentrated in high vegetable concentration blocks and among larger farms, indicating extremely limited diffusion overall.

Eleventh, herbicide use is less common than pesticide use, reported by about 28 percent of vegetable farms, reflecting the sensitivity of many vegetable crops to herbicide damage. Herbicide use is significantly more common in high vegetable concentration blocks than in low concentration blocks, and among farms in land tercile 3 relative to those in tercile 1. Higher adoption among larger farms likely reflects the labor-saving properties of herbicides.

Twelfth, mechanized land preparation is widespread. Sixty-eight percent of farms use four-wheel tractors, while smaller shares use power tillers (13 percent) and power weeders (3 percent). Interestingly, although tractor use is significantly more common in high vegetable concentration blocks than low (73 vs 57 percent), it does not differ significantly by landholding tercile. Power tiller use does not vary significantly across geographies or farm size classes, whereas power weeder adoption is significantly higher in high concentration blocks and among larger farms. While it may seem counterintuitive that large machines – tractors – should be scale neutral, while the smallest machines – power weeders – are not, we posit that this finding reflects the characteristics of machinery rental service markets, where tractors and power tillers are widely available for hire as outsourced services, whereas power weeders are usually owner-operated and rarely hired out.

Thirteenth, a few farmers (0.4 percent) have begun to use agricultural drones, likely to spray pesticides and/or liquid fertilizers. These farmers are all located in Cuttack district. Although agricultural drone adoption in Odisha is nascent, this confirmation of its existence suggests potential for future growth.

Fourteenth, practices that support product upgrading or value addition (grading and sorting, and washing) are widespread, practiced by 65 and 60 percent of farmers, respectively. Packing vegetables in crates or trays and bagging vegetables are also quite common, practiced by 22 and 31 percent of farmers. All these practices are used significantly more by large farms (land tercile 3), consistent with obtaining high volumes of production.

## The sequence of vegetable technology adoption

Figure 5 presents the sequence of adoption of technologies presented in Table 3, represented by the percentage of vegetable farmers in the sample reporting the first year in which the technology was used. The following broad patterns are apparent:

First, manure and inorganic fertilizers are the earliest widely adopted technologies. With 19 and 12 percent of the vegetable farmers surveyed in 2025, respectively, were already using in 1990. Adoption of both forms of fertilizer increased at a similar rate until around 2014, prior to which the share of farmers using manure was higher than the share using inorganic fertilizers. After 2014, the share of farmers using inorganic fertilizers for vegetable cultivation for the first time accelerated rapidly, overtaking the share using manure for the first time around 2019.

Second, first use of hybrid vegetable seed and hybrid rice seed by vegetable farmers increased slowly and at a similar rate from 1990 to 2014, after which time both increased rapidly, with rates of first use of hybrid vegetable seed outstripping hybrid rice seed particularly after 2019. First use of seed trays and purchased vegetable saplings began to grow slightly from a very low base from around 2018.

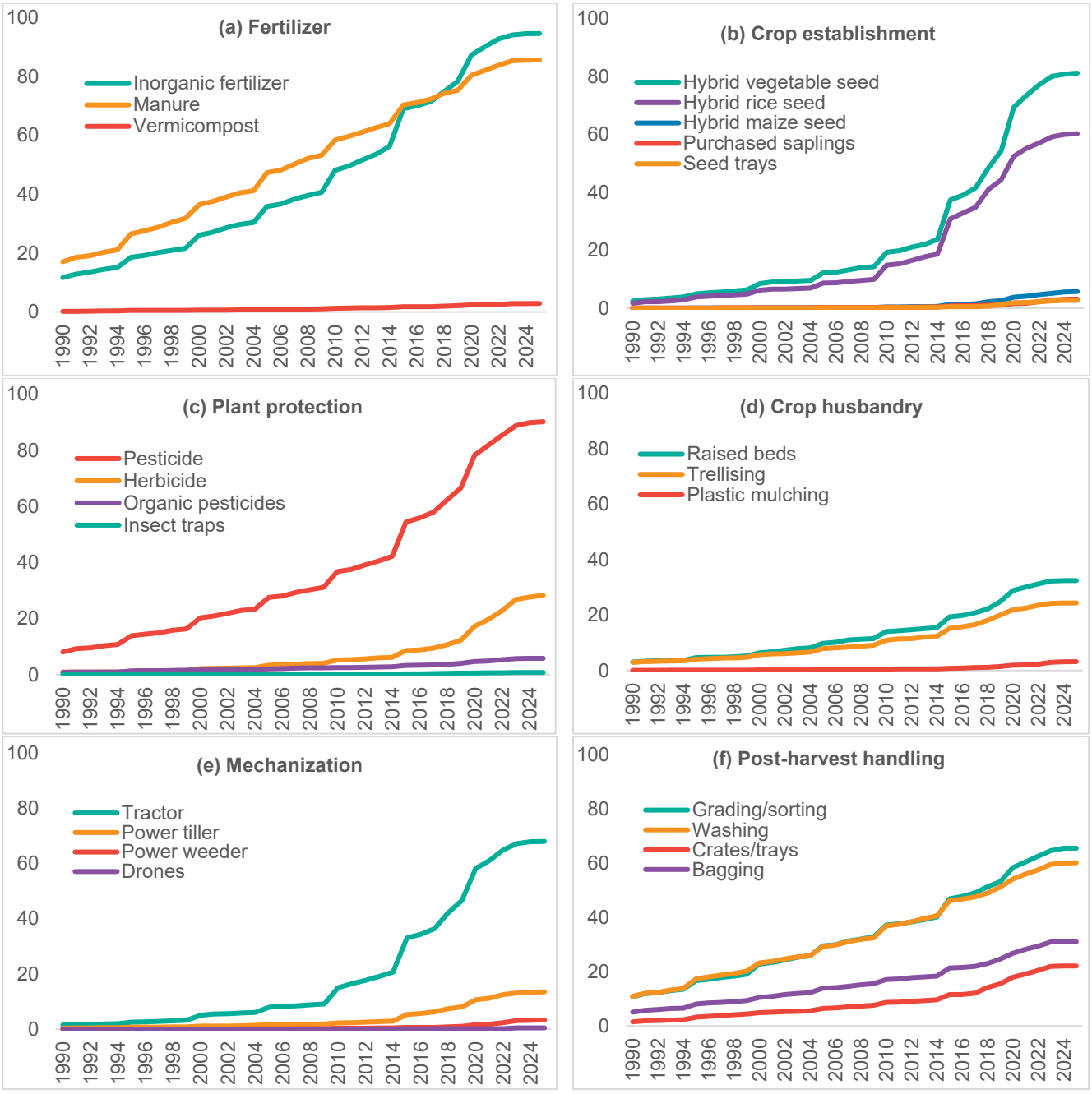
Third, pesticides were the earliest widely adopted input after manure and inorganic fertilizer. Year of first use follows a similar pattern to inorganic fertilizer, increasing at a steady rate until 2014 and accelerating rapidly thereafter. First use of herbicides in vegetable farming began around 2010 and increased slowly to 2019, accelerating thereafter.

Fourth, raised beds and trellising have a long history, with first use increasing incrementally until 2014 and growing at a slightly higher rate thereafter, with adoption of raised bed planting increasing more quickly thereafter.

Fifth, first use of tractors began somewhat later on average than adoption of inorganic fertilizers, pesticides and hybrid seed, with only 1 percent of current farmers having used them for vegetable cultivation, but followed a similar temporal pattern thereafter, beginning to accelerate after 2010, and accelerating further from 2014. First use of power tillers (two-wheel tractors) began around 2014, and power weeders, which are smaller than power tillers, from around 2020. Drones were first used in 2023. Interestingly, this sequence of miniaturization of agricultural machinery runs in the opposite direction to that found in many other locations (e.g. Southeast Asia) were small machines (power tillers) have been widely adopted before larger tractors.

Sixth, grading/sorting and washing were adopted early. Twelve percent of current farmers already used each practice in 1990. Rates of first use of both practices increased steadily and in step, suggesting that they may be adopted jointly. First use of crates, trays and bags also grew at a steady though slower rate, and from a lower base, with rate of respondents reporting first use increasing slightly after 2014.

**Figure 5:** Sequence of adoption of vegetable production technologies (percentage of vegetable farms reporting year of first use, by year) 1990-2025




**Source:** INCATA Odisha Farmer Survey 2025

## Irrigation

What accounts for the pattern of accelerating adoption of a bundle of complementary productivity enhancing vegetable cultivation technologies from around 2010 onwards? Analysis of the history of adoption of irrigation supplies part of the answer. Table 4 presents the share of irrigated parcels of land operated by surveyed farm households (including vegetable farmers, and non-vegetable farmers growing

mainly rice), by type of irrigation used and the type of irrigation provider (government, private or community), and well as rates of growth irrigation adoption over different time periods. The following points stand out.

First, irrigation is supplied by a mix of surface and groundwater sources. Canal irrigation is the most common type of irrigation (26 percent of irrigated parcels), followed by open wells (23 percent), tubewell/borewells (18 percent), lift irrigation (15 percent), rainwater harvesting (11 percent), and reservoirs or dams (8 percent).

Second, irrigation provided by government is most common, accounting for 55 percent of the total, followed by private sources (38 percent) and communities (7 percent).

Third, canal, lift, and dam irrigation are provided mainly by government, while open wells are mainly private. More than half of parcels receiving tubewell and rainwater harvesting irrigation are served by private irrigation, but these types of irrigation are also supplied by government (particularly borewells) and by communities (particularly rainwater harvesting).

Fourth, the number of parcels receiving irrigation for the first time has increased by 65 percent since 1980. The number of parcels receiving borewell irrigation increased fastest, growing by over 300 percent, followed by lift irrigation (133 percent). The number of parcels receiving open well irrigation and rainwater harvesting irrigation also increased substantially since 1980 (by 58 percent and 49 percent, respectively).

**Table 4:** Percentage of irrigated parcels and rate of growth in parcels irrigated, by irrigation type and provider.

| Type of irrigation | Irrigation provider: Government (%) | Irrigation provider: Private (%) | Irrigation provider: Community (%) | % of all irrigated parcels (%) | Growth, 1980-2025 (%) |
|---|---|---|---|---|---|
| **Irrigation canal (%)** | 95 | 2 | 4 | 26 | 47 |
| **Open well (%)** | 7 | 85 | 8 | 23 | 58 |
| **Tubewell/borewell (%)** | 38 | 58 | 4 | 18 | 304 |
| **Lift irrigation (%)** | 83 | 17 | 0 | 15 | 133 |
| **Rainwater harvesting (%)** | 23 | 51 | 26 | 11 | 49 |
| **Reservoir/dam (%)** | 85 | 5 | 10 | 8 | 17 |
| **Stream/waterfall (%)** | 0 | 0 | 100 | 0.1 | 16 |
| **Total (%)** | 55 | 38 | 7 | 100 | 65 |
| **Growth, 1980-2010 (%)** | 19 | 29 | 7 | 20 | - |
| **Growth, 2010-2025 (%)** | 35 | 67 | 14 | 43 | - |
| **Growth, 1980-2025 (%)** | 65 | 114 | 22 | 74 | - |

**Source:** INCATA Odisha Farmer Survey 2025

Fifth, expansion of irrigation access accelerated sharply after 2010, coinciding with a sharp uptick in adoption of productivity enhancing technologies in vegetable cultivation. From 1980 to 2010 the rate of

change in the number of parcels receiving irrigation from any source was slow, growing only 20 percent in 30 years. The number of privately irrigated parcels of land grew slightly faster, but from a lower base, than the number where irrigation was provided by government (29 percent vs 19 percent). In the 15 years from 2010 to 2025, the number of parcels receiving irrigation for the first time from any source increased by more than double the rate that it had in the preceding 30 years. Growth in the number of privately irrigated parcels from 2010-2025 (67 percent) outstripped that of government (35 percent) or community (14 percent) irrigated parcels.

**Table 5:** Percentage of irrigated parcels used for vegetable farming and rice farming, by type and source of irrigation

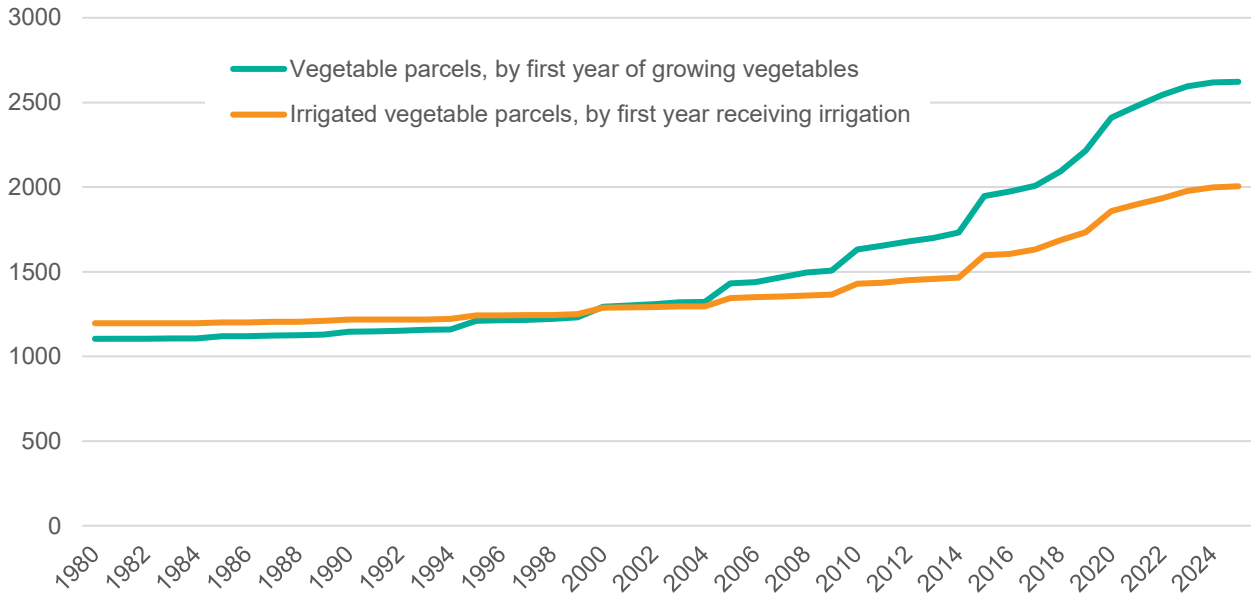
| Crop | Tubewell/ borehole | Open well | Lift irrigation | Canal | Reservoir/ dam | Rainwater harvesting | Stream/ waterfall |
|---|---|---|---|---|---|---|---|
| **Vegetables (%)** | 19 | 29 | 11 | 12 | 6 | 12 | 11 |
| ***Private (%)*** | 62 | 85 | 21 | 3 | 7 | 53 | 0 |
| ***Government (%)*** | 33 | 7 | 79 | 97 | 89 | 21 | 0 |
| ***Community (%)*** | 5 | 8 | 1 | 4 | 4 | 25 | 100 |
| **Rice (%)** | 11 | 12 | 16 | 33 | 9 | 7 | 13 |
| ***Private (%)*** | 50 | 85 | 11 | 1 | 4 | 45 | 0 |
| ***Government (%)*** | 48 | 11 | 89 | 95 | 84 | 32 | 0 |
| ***Community (%)*** | 3 | 5 | 0 | 4 | 13 | 23 | 100 |

Source: INCATA Odisha Farmer Survey 2025

Table 5 further disaggregates the type and source of irrigation used on parcels of land used to grow vegetables, and parcels used to grow rice. Open wells and borewells are the two most common types of irrigation in vegetable farming, used to irrigate 29 percent and 19 percent of parcels of irrigated vegetable land, respectively. Canals and lift irrigation are the two forms of irrigation most commonly used to grow rice, used to supply water to 33 percent and 16 percent of irrigated rice parcels, respectively. Notably, open wells and borewells are mainly privately owned, while canals and lift irrigation are primarily provided by government. Thus, although growers of vegetables and rice use a mixture of types of irrigation from a variety of sources for both crops, government irrigation schemes are predominantly targeted at, and used for, rice farming, whereas vegetable cultivation is heavily dependent on private irrigation.

Figure 6 illustrates the importance of irrigation access as a catalyst for vegetable cultivation, showing the cumulative number of parcels of land under vegetable cultivation by first year brought under vegetable cultivation, and the cumulative number of vegetable parcels by first year of receiving irrigation. A substantial number of respondents were unable to say in which year one or both these events took place. ‘Don’t know’ responses were dropped’ and ‘always’ responses were assumed to refer to before 1980. Despite these recall limitations a clear association can be seen between date of irrigation acquisition and entry into vegetable farming. The cumulative numbers of parcels receiving irrigation and under vegetable cultivation both grew very gradually from 1980 to 2000. The rates of growth of both increased slightly from 2000 to 2015 and accelerated thereafter, both tracing a similar trajectory, but with number of parcels brought under vegetable cultivation outstripping number of vegetable parcels newly receiving irrigation for the first time.

**Figure 6:** Cumulative count of parcels of land brought under vegetable cultivation, and irrigated vegetable parcels, by year of first receiving irrigation, 1980-2025




**Source:** INCATA Odisha Farmer Survey 2025 Note: Assumed pre-1980 as start date for parcels brought under vegetable cultivation of irrigation where respondent reported 'always' as date.

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