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Zero Budget Natural Farming in Andhra Pradesh: A Review of Evidence, Gaps, and Future Considerations

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Summary

Zero Budget Natural Farming (ZBNF), also referred to as Community Managed Natural Farming (CMNF), is one of the largest efforts to implement agroecology at scale. The Government of Andhra Pradesh, India plans to expand ZBNF to millions of farmers in the state over the next several years. This review clarifies what is included (and excluded) in defining ZBNF, describes the evolution of ZBNF as a production and social framework, assesses available evidence for impacts that result from the implementation of ZBNF, and identifies gaps in the knowledge in the evidence base.

Introduction

Tufts and Woodwell Climate Research Center researchers meet with farmers in Andhra Pradesh to learn about ZBNF.

Agricultural intensification, characterized by increasing physical, managerial, and capital inputs resulting in increased production or output, has been a common strategy for many decades, in both industrialized and developing countries. The success of this strategy at the farm level (including household income) and the country level (meeting food security goals) has been uneven, and increased yield is generally prioritized over other outcomes. In countries like India, which are still dominated by smallholder farms, there are many obstacles to an intensification approach, such as constraints on the ability to purchase inputs and the difficulty in applying this approach at smaller scales.

In India and elsewhere, there are numerous approaches that are counter to conventional forms of agricultural intensification, including agroecological principles, sustainable and organic agriculture, and permaculture. All of these generally take into account both the physical and social aspects of agriculture and the broader food system, and at least to some degree utilize or modify traditional practices appropriate to the country or region. Optimization and the recognition of trade-offs (implicit or explicit) across and within these domains are hallmarks of the assessment of sustainability of food system function and outcome. There are numerous conceptual frameworks that illustrate the need to assess outcomes across domains (e.g., TEEB 2018; Webb et al. 2020). There are far fewer frameworks that either propose or use specific metrics and indicators. An example of the latter is Gustafson et al. (2016), which proposed specific, country-level metrics. Subsequently, Chaudhary et al. (2018) applied this assessment framework, using from two to six indicators with seven metrics (food nutrient adequacy, ecosystem stability, affordability and availability, sociocultural wellbeing, resilience, food safety, and waste and loss reduction). These frameworks can be used to examine the impacts of emerging agroecological approaches on sustainability domains and interactions between domains.

One of the largest efforts to implement agroecology at scale is Zero Budget Natural Farming (ZBNF), recently also referred to as Community Managed Natural Farming (CMNF), which has been codified as state policy in Andhra Pradesh, India. The stated goal in Andhra Pradesh is to transition the approximately 6 million farms in the state to ZBNF by 2027 (Khurana and Kumar 2020; Reddy et al. 2019; RySS 2019). ZBNF represents a dramatic change in the mode of production that specifically rejects and reverses reliance on purchased inputs (especially inputs such as manufactured fertilizers and pesticides). The history and evolution of ZBNF (described briefly below) also indicates that socioeconomic change, particularly improved rural livelihoods and women's empowerment, and environmental outcomes (e.g., improved soil health, climate adaptation) are key desired goals. Although there have been numerous claims of positive outcomes across agricultural, environmental, and socioeconomic domains, there have been few empirical assessments of ZBNF across these domains. Thus, the purposes of this review are to:

1. Clarify what is included (and excluded) in defining ZBNF.
2. Briefly document the evolution of ZBNF as a production and social framework.
3. Assess available evidence from peer-reviewed and grey literature (including NGO and government reports) for impacts that result from the implementation of ZBNF.
4. Identify gaps in the knowledge in the evidence base.

Tufts and Woodwell Climate Research Center researchers with Indian farmers.

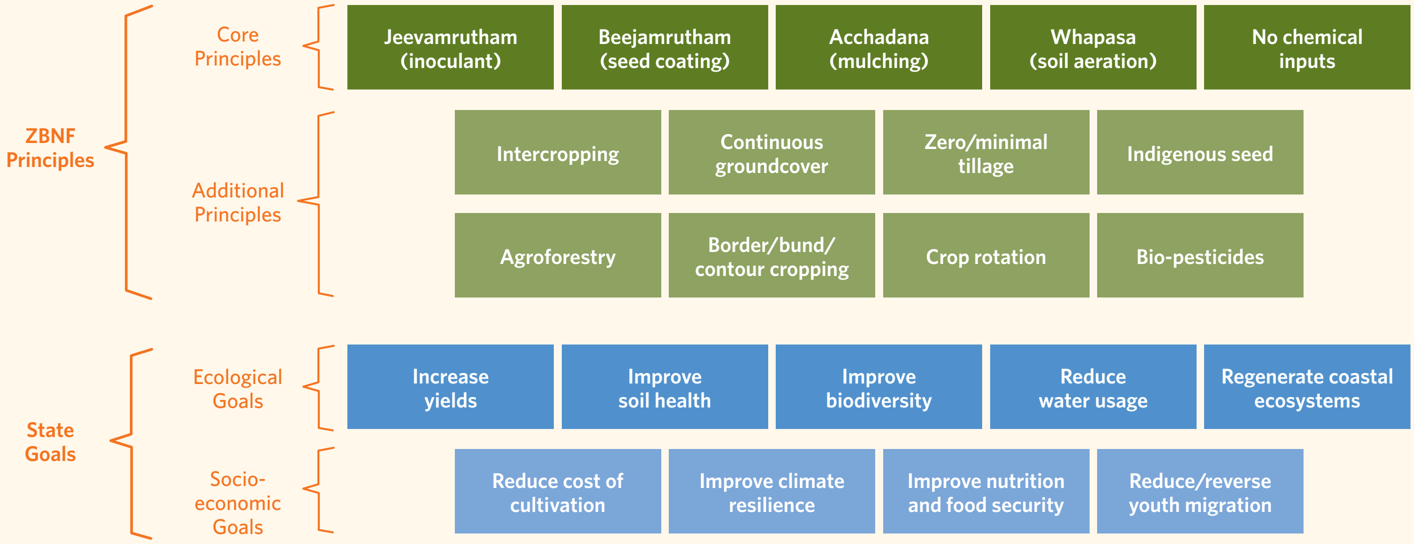
Methods

A literature search was conducted in 2020 using the Tufts University library catalog, Google Scholar, and Google to identify peer-reviewed literature and grey literature related to ZBNF. Search strings included "Zero Budget Natural Farming" and its core elements (jeevamrutham, beejamrutham, acchadana, whapasa). Thirty-two publications available from 2013 to 2020 were included in this review. This review does not include non-English literature which is a key limitation.

Definition of ZBNF

Zero Budget Natural Farming was developed by Subhash Palekar in the mid-1990s in Maharashtra (Biswas 2020). The practice originally consisted of four core elements: 1) *jeevamrutham,* a soil inoculant made of cow dung, urine, pulse flour, jaggery, and soil; 2) *beejamrutham,* a seed coating made of similar ingredients; 3) *acchadana,* mulching; and 4) *whapasa,* soil aeration, as an outcome of the other three principles (Khadse et al. 2018). These practices address a broad range of goals, including stimulating microbial activity, increasing soil carbon, adding nitrogen through green mulching, and accelerating the availability of existing nitrogen in the topsoil (Smith et al. 2020). ZBNF, as defined by the Government of Andhra Pradesh, has evolved from Palekar's teachings to include regenerative practices such as continuous groundcover and the five-layer model, which is a specific type of intercropping (Figure 1). Key features of ZBNF that are consistent with its founding are the use of natural inputs and, where available, the use of indigenous seed.

Figure 1: ZBNF principles and objectives



Bharucha et al. 2020; Bishnoi & Bhati 2017; Biswas 2020; Das 2020; Gupta and Jain 2020; Khadse et al. 2018; La Via Campesina 2016; Mishra 2018; Reddy et al. 2019; RySS 2019

To be classified as a ZBNF farmer, a farmer must not use chemical inputs or genetically modified seed and must adopt at least one of the core wheels of ZBNF (Gupta and Jain 2020). ZBNF's broad definition gives farmers flexibility to adopt the practices that are most suitable for their needs. Farmers range from only using jeevamrutham and beejamrutham on a subplot of their land to adopting all elements of ZBNF on their entire landholding. This spectrum is practical for farmers but complicates building the scientific evidence base for ZBNF, because it is difficult to identify ZBNF farmers and attribute impacts to specific ZBNF practices.

Motivation for ZBNF Movement

This section describes the Government of Andhra Pradesh's motivations for establishing the ZBNF program, including challenges associated with conventional agriculture, socioeconomic factors, and climate change.

Moving away from conventional agriculture. Following the Green Revolution, Indian agriculture has been characterized by high yielding varieties grown in high chemical input systems (Agoramoorthy 2008). Though the Green Revolution succeeded in increasing yield, it also resulted in negative externalities like soil degradation, water pollution, and increased costs of inputs, to name a few (Bhattacharyya et al. 2015). In addition to the negative environmental impacts, these systems have left farmers in a cycle of debt which have resulted in social and financial problems contributing to outmigration to cities and farmer suicides (Chindarkar 2007; Meek and Khadse 2020). These social, economic, and environmental consequences stemming from conventional farming have motivated the rise of ZBNF in several states throughout India, with the goal of creating a more effective and just agricultural system.

Socioeconomic considerations. In addition to being a movement to improve economic and environmental outcomes of smallholder farming, ZBNF is also a social movement to alleviate farmer distress and empower women and landless agricultural workers. Within the last decade, 100,000 farmers have committed suicide in India, in part due to more frequent droughts and overwhelming debt (Meek and Khadse 2020). Evidence from Anantapur, a drought-prone district in the Rayalaseema region of Andhra Pradesh, suggests distress from debts and crop failure are primary reasons for suicide, compounded by degrading soil quality and other socio-cultural factors (Chindarkar 2007). Evidence from focus groups have shown a general displeasure with farming, and a large-scale survey found that roughly 40 percent of Indian farmers do not like farming, leading to outmigration, particularly from young people who do not see farming as a viable profession (Agarwal and Agrawal 2017). Outmigration from rural areas to urban centres is threatening rural agrarian livelihoods, motivating action from the government to improve the lives of farmers (Chandrasekhar and Sahoo 2019).

Male farmers' increased migration to urban areas has contributed to women's increased participation in farming as unpaid family laborers (Sharma and Nayak 2019). In Andhra Pradesh, approximately 50 percent of women age 15 to 49 worked as unpaid family laborers compared to an average of approximately 28 percent across India (Sharma and Nayak 2019). Moreover, low wages and low demand for labor also pressure landless agricultural workers to migrate. The Government of Andhra Pradesh intends for the ZBNF program to improve income for women and landless laborers by facilitating land leasing and creating opportunities for off-farm income, such as selling inputs. Lastly, health-related concerns about dietary diversity and chemical residues in produce also motivated the Government of Andhra Pradesh to scale up natural farming (RySS 2019).

The purpose of the ZBNF program is not only to increase farm income, but to address social problems by giving more autonomy to the farmer. Focus groups have shown farmers' mental well-being to be better when free from debt with the autonomy to shape their production systems as they please (Meek and Khadse 2020). In this way, ZBNF is a movement which focuses on food sovereignty, and shifts agricultural control to individuals, and away from large corporations and banks, which can trap farmers in a cycle of debt.

Climate change-related motivations. One of the primary reasons that the Government of Andhra Pradesh promotes ZBNF is because of its potential climate change adaptation and mitigation benefits. Andhra Pradesh has six agro-climatic zones and 13 districts with varying rainfall, levels of soil degradation, and exposure to cyclonic hazards. Andhra Pradesh's climate vulnerability in the agriculture sector is mostly tied to decreases in rainfall and increased temperatures, with each district's vulnerability being dependent on the anticipated effects of climate change, and the climate sensitivity and adaptive capacity of the district (Rama Rao et al. 2017).

“ANDHRA PRADESH'S CLIMATE VULNERABILITY IN THE AGRICULTURE SECTOR IS MOSTLY TIED TO DECREASES IN RAINFALL AND INCREASED TEMPERATURES...”

Excessive tillage, deforestation, imbalanced use of fertilizers, and other unsustainable agricultural practices have led to soil degradation in parts of Andhra Pradesh, contributing to the state's climate vulnerability (Bhattacharyya et al. 2015). Soil degradation also leads to high levels of water erosion, resulting in an estimated 5.3 billion tons of topsoil loss in India annually (Bhattacharyya et al. 2015). ZBNF proponents state that it can help farmers adapt to rainfall variability by reducing soil degradation.

ZBNF proponents also state this practice can mitigate climate change by reducing synthetic fertilizer use and increasing soil carbon sequestration. Changes in water use from diesel-powered irrigation pumps and fuel use from other mechanized agricultural equipment also have implications for greenhouse gas emissions (CSTEP 2020).

In addition to potential climate mitigation benefits, decreases in fertilizer and water use have economic benefits for the state government as well. The Government of Andhra Pradesh is motivated by the potential to decrease fertilizer and water subsidies to farmers, as it spent 9.76 million USD on fertilizer subsidies in 2018–2019 (Gupta et al. 2020). If ZBNF can be productive without chemical inputs, sequester carbon in the soil, increase soil water holding capacity, and build climate-resilient farming systems, it could significantly reduce government spending to support India's farmers, and foster healthier soil in the long term.

Scaling Up ZBNF in Andhra Pradesh

Following the success of natural farming under previous poverty alleviation programs in the state, the Government of Andhra Pradesh expanded ZBNF in 2015. Andhra Pradesh's Department of Agriculture appointed Rythu Sadhikara Samstha (RySS) to oversee the "Climate Resilient Zero Budget Natural Farming" program. RySS, a state-run research institute, was established to train farmers and promote farmer-to-farmer learning. The state launched ZBNF as a pilot program with over 700 villages and approximately 40,650 farmers in 2016 (RySS 2019). As of March 2020, approximately 623,300 farmers were enrolled in Andhra Pradesh's ZBNF program (almost 10.5 percent of all farmers in Andhra Pradesh), and the total amount of land cultivated under ZBNF was almost three percent of total net sown area in the state (181,600 hectares) (Khurana and Kumar 2020). By 2027, Andhra Pradesh plans to expand ZBNF to all 6 million farmers and 8 million hectares (RySS 2019).

The ZBNF program is funded by the national and state government through Paramparagat Krishi Vikash Yojana and Rashtriya Krishi Vikash Yojana programs, as well as other partners, including the Azim Premji Philanthropic Initiative, the International Fund for Agricultural Development, and the Bill & Melinda Gates Foundation (Mishra 2018; RySS 2019). The cost to RySS to transition one farmer to ZBNF is approximately 25,550 INR (348 USD), where 73 percent of the cost is dedicated to capacity building (RySS 2019). Farmers do not receive a subsidy from the government to adopt ZBNF (Gupta and Jain 2020).

ZBNF's rapid expansion in the state can be attributed to the program's extensive network of fellows to recruit and train farmers, along with its strategic linkage with women's self-help groups. In each village where the program is active, 50 Community Resource Persons (CRPs), who have previously been identified as "champion farmers" for their success with ZBNF, train other farmers in their community, provide marketing support, and collect data for RySS (RySS 2019). Recent agricultural graduates are also stationed in a village for two years as Natural Farming Fellows where they lease land and practice ZBNF to demonstrate its viability to nearby farmers. Natural Farming Fellows adapt ZBNF's core elements to local conditions and help to attract youth to the program (Gupta and Jain 2020).

> “ZBNF'S RAPID EXPANSION IN THE STATE CAN BE ATTRIBUTED TO THE PROGRAM'S EXTENSIVE NETWORK OF FELLOWS TO RECRUIT AND TRAIN FARMERS, ALONG WITH ITS STRATEGIC LINKAGE WITH WOMEN'S SELF-HELP GROUPS.”

Women's self-help groups are instrumental in scaling up ZBNF. Millions of women in self-help groups across Andhra Pradesh collectively invest their own savings, loans, and government grants into their communities (Deshmukh-Ranadive 2004). As of 2019, more than 161,000 women's self-help groups were mobilizing

farmers to adopt ZBNF, preparing farming plans, marketing ZBNF locally, and monitoring farmers' progress (RySS 2019). RySS relies on women's self-help groups to identify landless farmers to participate in kitchen gardens or lease land (Gupta and Jain 2020). Women's self-help groups are also a source of financial capital for farmers during their transition to ZBNF (Gupta and Jain 2020).

ZBNF is promoted as a solution to the farmer debt crisis and environmental degradation in Andhra Pradesh and throughout other states in India as well. Himachal Pradesh is promoting ZBNF under the state-sponsored scheme, "Prakritik Kheti Khushal Kisan" (Department of Agriculture Himachal Pradesh). ZBNF is also practiced in Karnataka, Kerala, Haryana, and Gujarat (Khurana and Kumar 2020), and continues to attract international attention as a burgeoning agroecological movement.

Fertilizers and bio-pesticides produced by ZBNF farmers.

Review of Evidence of ZBNF Impacts

ZBNF's current evidence base is promising but limited in scope. There is strong evidence that ZBNF improves farmer income by reducing cultivation costs across most of the predominantly grown crops in the state. Research on yield is encouraging, though inconclusive. Although women and youth are central to ZBNF's scaling, there is a lack of research on the gendered impacts of the program and its effects on youth interest and migration.

This section describes evidence on ZBNF adoption, economic impacts, and yield impacts, and then summarizes potential climate, ecological, and social considerations that have been discussed in literature but not empirically evaluated. We conclude with an overview of the evidence gaps in ZBNF literature, which include ZBNF's effects on food security, gender equality, migration, climate mitigation, and climate resilience.

ZBNF ADOPTION

This section describes patterns of ZBNF adoption, typical characteristics of ZBNF farmers, their reasons for adopting ZBNF, barriers to adoption, and evidence of dis-adoption.

Partial adoption. Some farmers reduce the risks associated with adopting ZBNF by experimenting with only a subset of ZBNF practices, most commonly jeevamrutham and beejamrutham (Gupta et al. 2020). This incremental adoption of ZBNF practices is referred to as a vertical transition (Gupta et al. 2020) and also as stacking (especially when there are two or more practices implemented at the same time). Some farmers also choose to adopt ZBNF on only a portion of their land. RySS expects that a farmer will typically adopt ZBNF on a quarter of their landholding in the first year, half of their landholding in the second year, and complete adoption during the third year—a process described as a horizontal transition (Gupta et al. 2020; RySS 2019). As a result, the land area under ZBNF adoption is lower than the total amount of land associated with farmers in the ZBNF program.

Farmer characteristics. Farm size and education are the most predictive farmer characteristics for ZBNF adoption. Most ZBNF farmers have small to medium sized landholdings (Gupta et al. 2020; Khadse et al. 2018). The Council on Energy, Environment, and Water (CEEW) surveyed 581 farmers (254 ZBNF, 327 non-ZBNF) in six districts in Andhra Pradesh. More than 70 percent of ZBNF farmers surveyed were marginal farmers (owning or renting less than 2.5 acres), approximately 20 percent were small farmers (2.5 to 5 acres), and the remaining percentage were large farmers (more than 5 acres) (Gupta et al. 2020). In Karnataka, approximately 72 percent of ZBNF farmers surveyed owned less than 10 hectares (Khadse et al. 2018).

On average, ZBNF farmers received more education than non-ZBNF farmers. Forty-two percent of non-ZBNF farmers surveyed in Gupta et al. (2020) did not receive any formal schooling, compared to only 20 percent of ZBNF farmers (Gupta et al. 2020). Based on a survey of 60 farmers in Andhra Pradesh, one study concluded that education has a positive, statistically significant impact on farmers' perception of ZBNF (Sarada and Kumar 2018).

A small proportion of women relative to men adopt ZBNF, although more than 161,000 women's self-help groups form the foundation of the program (RySS 2019). Gupta et al. (2020) found that 4 and 7 percent of conventional and ZBNF farmers surveyed, respectively, were women. Women in Andhra Pradesh typically participated in the ZBNF program by selling inputs, marketing to other farmers in the community, and monitoring farming plans (RySS 2019; Tripathi et al. 2018).

Studies did not observe significant differences between ZBNF and non-ZBNF farmers by caste. Scheduled Caste and Scheduled Tribe farmers represent the smallest share of ZBNF farmers, followed by the general or Other Backward Class (Gupta et al. 2020; RySS 2019).

Reasons for adoption. Farmers primarily chose to adopt ZBNF to reduce the cost of cultivation (Bishnoi and Bhati 2017; Biswas 2020; Khadse et al. 2018; Khurana and Kumar 2020; Mier y Terán Giménez Cacho et al. 2019; Münster 2017). Since ZBNF does not require chemical inputs, overall input costs decrease dramatically, thereby reducing the need for credit to purchase chemical inputs. One farmer stated that costs were so low that he was no longer concerned with achieving a certain yield to return a profit (Bishnoi and Bhati 2017). Khurana and Kumar (2020) conducted focus groups with 142 farmers across five districts and

found that 100 percent of farmers surveyed felt their costs decreased under ZBNF (Khurana and Kumar 2020). In a concurrent survey of 40 farmers, 90 percent of farmers believed costs decreased under ZBNF, and 10 percent felt that costs remained the same as in conventional farming (Khurana and Kumar 2020). In the Prakasam district of Andhra Pradesh, farmers held diverging views on the cost impacts of ZBNF (Sarada and Kumar 2018). Forty-five percent of farmers surveyed in Prakasam believed that ZBNF did not reduce costs relative to conventional farming, and 42 percent believed ZBNF did reduce costs. The remaining 13 percent were undecided (Sarada and Kumar 2018). The results in Prakasam were likely different from the aforementioned studies due to changes in labor costs.

In Karnataka, farmers primarily adopted ZBNF due to health benefits (presumably from reduced exposure to chemicals), followed by food self-sufficiency, environmental reasons, and reduced costs and debt (Khadse et al. 2018). Other motivations for adopting ZBNF in Karnataka included economic independence from corporations and spiritual reasons (Khadse et al. 2018).

Barriers to adoption. Research has shown that barriers to ZBNF adoption include time and labor constraints, access to cows, land access, and tenant farmer arrangements (Bhattacharya 2017; Galab et al. 2019a; Khurana and Kumar 2020). Small farmers noted that ZBNF input preparation is time and labor intensive (Galab et al. 2019a; Gupta et al. 2020; Khurana and Kumar 2020; Reddy et al. 2019). Gupta et al. (2020) concluded beejamrutham required the most labor out of all ZBNF inputs due to manual seed coating and hand-mixing of ingredients (Gupta et al. 2020). The Centre for Study of Science, Technology, and Policy (CSTEP) surveyed 120 farmers and reported that each acre of paddy under ZBNF required 60 hours of work from men, 800 hours from women, and 10 hours of bullock labor, compared to 110 hours of work from men, 530 hours from women, and 40 hours of bullock labor per non-ZBNF acre (CSTEP 2020). Studies found that large farmers were less likely to adopt ZBNF due to labor and time constraints, as the increased costs to hire labor affected their profitability (Das 2020; Gupta et al. 2020; Khurana and Kumar 2020). One author claimed ZBNF was not profitable for farmers owning more than five acres (Das 2020). Although ZBNF's farmer-to-farmer network helps to fill knowledge gaps on implementation, knowledge about how to prepare and use bio-pesticides (e.g., neemastra, agniastra, brahmastra) is still a constraint to adoption (Galab et al. 2019a; Sarada and Kumar 2018).

“RESEARCH HAS SHOWN THAT BARRIERS TO ZBNF ADOPTION INCLUDE TIME AND LABOR CONSTRAINTS, ACCESS TO COWS, LAND ACCESS, AND TENANT FARMER ARRANGEMENTS.”

Access to cows is another barrier to adoption (Bhattacharya 2017; Galab et al. 2019a; Khurana and Kumar 2020). One author estimated the cost of a native cow at 15,000 INR (approximately 200 USD) (Bhattacharya 2017). Another source stated that there was a scarcity of cows in Andhra Pradesh (Galab et al. 2019a). According to one study, farmers concluded one indigenous cow could produce enough inputs for approximately five acres of land, compared to 30 acres according to RySS (Khurana and Kumar 2020). Additionally, in Bihar, almost one third of women surveyed who chose not to adopt ZBNF identified lack of livestock as their main barrier (Kc et al. 2015). Some farmers overcome these input-related barriers by buying inputs from input shops, purchasing cow inputs from other farmers who owned cows, or joining groups where farmers share inputs and labor (Galab et al. 2019a; Neelam and Kadian 2016).

Land access is also a barrier to participation in ZBNF. In the aforementioned study in Bihar, half of the women surveyed who did not adopt ZBNF cited lack of land as their primary reason (Kc et al. 2015). Recognizing land as a barrier to participation, RySS assists landless workers with land leasing, promotes off-farm activities (e.g., backyard poultry), and encourages participation in ZBNF kitchen gardens (RySS 2019).

Tenant farmers face barriers to adoption during the initial transition period from conventional farming to ZBNF (Gupta and Jain 2020). Authors of a ZBNF crop cutting study stated, "existing structures of land relations like tenancy contracts and social structure of villages…may become barriers/drivers for the adoption of ZBNF" (Galab et al. 2019a). One tenant farmer noted he could not adopt ZBNF, because the land that he leases rotates between different farmers, including conventional farmers (Khurana and Kumar 2020). He would have to risk farmers using conventional methods on parcels that he previously converted to ZBNF (Khurana and Kumar 2020).

Dis-adoption. Though there are not yet comprehensive data on dis-adoption of ZBNF, there is evidence from focus groups that some farmers who previously converted to ZBNF are moving back to conventional agriculture (Reddy et al. 2019). Dis-adoption has occurred among some medium and large-scale farmers who are not able to supply the labor necessary to practice ZBNF and cannot afford to hire additional farmworkers (Gupta and Jain 2020). Additionally, large scale conventional farms are typically more profitable than small scale conventional farms and can afford chemical inputs associated with conventional agriculture (Khadse et al. 2018). Trade-offs between chemical input and labor costs along with their effects on adoption or dis-adoption have not been empirically assessed. It is possible that large scale farmers do not benefit financially from transitioning to ZBNF, and therefore have less incentive to adopt the practices.

As discussed, tenant farmers are another group which encounter barriers to ZBNF adoption. Some tenant farmers have stopped practicing ZBNF because it has affected their ability to pay rent, and there isn't enough flexibility in their contracts to allow them to experiment with new production systems (Gupta and Jain 2020;

Khurana and Kumar 2020). Further, there is little financial assistance from the government during the three-year transition period in moving from conventional agricultural to practicing ZBNF. As a result, adopting ZBNF jeopardizes tenant farmers' ability to pay rent in the short term, even if there are financial gains in the long term (Gupta and Jain 2020).

ECONOMIC EVIDENCE

This section describes ZBNF's impacts on net income and the cost of cultivation. ZBNF improves farmers' net income based on the literature reviewed (Bharucha et al. 2020; Bishnoi and Bhati 2017; Biswas 2020; Das 2020; Galab et al. 2019a, 2019b; Gupta et al. 2020; Khurana and Kumar 2020; Mishra 2018). The median net income for non-ZBNF farmers in the literature reviewed is approximately 480 USD per hectare (35,210 INR per hectare) in one season, with an interquartile range of 270 to 760 USD per hectare (Galab et al. 2019a, 2019b; Koner and Laha 2020; Reddy et al. 2019). ZBNF increased net income by a median of 35 percent (interquartile range of 10 to 80 percent), with the exception of Reddy et al. (2019) who reported 3 to 8 percent decreases for cotton, banana, and sunflower due to decreases in yield (Reddy et al. 2019). Intercropping, bund crops, and border crops helped to smooth income for farmers throughout the year (Galab et al. 2019a). Table 1 presents the percent difference in net income relative to non-ZBNF and ZBNF plots for major crops in Andhra Pradesh during the Kharif (wet) and Rabi (dry) seasons.

Table 1: Changes in NET INCOME under ZBNF relative to non-ZBNF for major crops

Crop	+/–	Percent difference in net income relative to non-ZBNF	Season/Year	Source
Paddy	+	100%	2014-15	Koner and Laha 2020
	+	48%	Rabi 2018-19	Galab et al. 2019b
	+	10%	N/A	Reddy et al., 2019
	+	9%	Kharif 2018-19	Galab et al. 2019a
Groundnut	+	41%	Kharif 2018-19	Galab et al. 2019a
	+	33%	Rabi 2018-19	Galab et al. 2019b
	+	2%	N/A	Reddy et al. 2019
Black gram	+	84%	Rabi 2018-19	Galab et al. 2019b
Cotton	+	45%	Kharif 2018-19	Galab et al. 2019a
	-	-3%	N/A	Reddy et al. 2019
Bengal gram	+	133%	Rabi 2018-19	Galab et al. 2019b
	+	17%	Kharif 2018-19	Galab et al. 2019a

The sample size for each study listed is as follows: Galab et al. (2019a) – 1,365 farmers, Galab et al. (2019b) – 386 farmers, Koner and Laha (2020) – 50 farmers. Sample sizes for Mishra (2018) and Sarial (2019) were not reported. All studies were conducted in Andhra Pradesh except for Sarial (2019) and Koner and Laha (2020), which were conducted in Himachal Pradesh and West Bengal, respectively.

CCE – crop cutting experiment, N/A – Not available

See Table 5 on page 24 for data on additional crops.

ZBNF improvements to net income are largely driven by decreases in input costs (Bharucha et al. 2020; Bishnoi and Bhati 2017; Biswas 2020; Das 2020; Galab et al. 2019a, 2019b; Gupta et al. 2020; Khurana and Kumar 2020; Mishra 2018). In some cases, net income increased regardless of yield declines due to large reductions in input costs (Bishnoi and Bhati 2017; Galab et al. 2019a; Khurana and Kumar 2020). Production costs declined for all evaluated crops except groundnut (Table 2). Gupta et al. (2020) observed that groundnut cultivation costs increased by 34 percent under ZBNF relative to conventional farming due to the increasing cost of seed and labor (Gupta et al. 2020). The Centre for Economic and Social Studies (CESS) found that during the Kharif season, cultivation costs declined the most for tomato and cotton, whereas during the Rabi season, reductions in cultivation costs were largest for paddy, maize, jowar, and pulses (Galab et al. 2019a, 2019b). These results suggest ZBNF can reduce costs for farmers especially in Kurnool and Guntur, where most cotton and jowar are grown in Andhra Pradesh (Andhra Pradesh Directorate of Economics and Statistics 2017).

Table 2: Changes in CULTIVATION COST under ZBNF relative to non-ZBNF for major crops

Crop	+/-	Percent difference in cost relative to non-ZBNF	Season/Year	Source
Paddy	-	-2%	2014-15	Koner and Laha 2020
	-	-11%	Kharif 2019	Gupta et al. 2020
	-	-14%	Kharif 2018-19	Galab et al. 2019a
	-	-29%	Rabi 2018-19	Galab et al. 2019b
	-	-41%	N/A	Reddy et al. 2019
Groundnut	+	34%	Kharif 2019	Gupta et al. 2020
	-	-2%	Kharif 2018-19	Galab et al. 2019a
	-	-3%	Rabi 2018-19	Galab et al. 2019b
	-	-10%	N/A	Reddy et al. 2019
Black gram	-	-20%	Rabi 2018-19	Galab et al. 2019b
Cotton	-	-11%	N/A	Reddy et al. 2019
	-	-17%	Kharif 2018-19	Galab et al. 2019a
Bengal gram	-	-14%	Kharif 2018-19	Galab et al. 2019a
	-	-38%	Rabi 2018-19	Galab et al. 2019b

The sample size for each study listed is as follows: Galab et al. (2019a) – 1,365 farmers, Galab et al. (2019b) – 386 farmers, Koner and Laha (2020) – 50 farmers. Sample sizes for Mishra (2018) and Sarial (2019) were not reported. All studies were conducted in Andhra Pradesh except for Sarial (2019) and Koner and Laha (2020), which were conducted in Himachal Pradesh and West Bengal, respectively.

CCE – crop cutting experiment, N/A – Not available

See Table 6 on page 24 for data on additional crops.

Labor costs increased for some ZBNF farmers, countering the effect of decreased chemical input costs on net income (Galab et al. 2019a; Gupta et al. 2020; Khurana and Kumar 2020). For paddy in the Kharif season, CESS reported that net income increased more in non-delta districts compared to delta districts (East Godavari, West Godavari, Krishna, and Guntur), likely due to higher labor costs in delta districts and decreased yields (Galab et al. 2019a). Decreases in input costs may be driving increases in income, but changes in labor costs and yield also affect profitability.

Several studies noted that ZBNF produce lacks a market premium (Biswas 2020; Das 2020; Galab et al. 2019a; Khurana and Kumar 2020; Koner and Laha 2020; La Via Campesina 2016). Market premiums can further improve net incomes, especially if there are yield declines in initial transition years. Based on focus group discussions with 142 farmers in Andhra Pradesh, one study revealed that 87 percent of farmers did not receive a price premium (Khurana and Kumar 2020). The remaining 13 percent of farmers were able to receive higher prices for ZBNF through their own connections, marketing, and support from organizations (Khurana and Kumar 2020).

> **“POLICY CONSIDERATIONS INCLUDING MARKET PREMIUMS, SUBSIDIES FOR ADOPTION, AND DECREASED FERTILIZER SUBSIDIES COULD MAKE ZBNF MORE OR LESS ECONOMICALLY ATTRACTIVE FOR FARMERS.”**

Subsidies also affect the profitability of ZBNF. A study in West Bengal assumed ZBNF paddy farmers received a subsidy of 4,135 INR (56 USD), which almost doubled net income (Koner and Laha 2020). Without the subsidy, net income would have decreased by 11 percent (Koner and Laha 2020). The Government of India subsidizes chemical fertilizers, primarily urea which represented 60 percent of the proposed budget for fertilizer subsidies in 2019–2020 (Economic Times 2019; Gupta et al. 2020). If fertilizer subsidies were removed, input costs would decrease by even more under ZBNF relative to conventional farming (Galab et al. 2019b; Gupta et al. 2020). Policy considerations including market premiums, subsidies for adoption, and decreased fertilizer subsidies could make ZBNF more or less economically attractive for farmers.

YIELD EVIDENCE

This section provides an overview of the literature on ZBNF's impacts on yield. Evidence on yield impacts of ZBNF is mixed, depending on the crop and the region of production. Although a full transition to ZBNF usually takes three years, most yield studies only evaluate changes over a single year. For this reason, single year studies are presented in Table 3, and multi-year studies are presented in Table 4.

Table 3: Changes in YIELD under ZBNF relative to non-ZBNF for major crops

Crop	+/-	Percent difference in yield relative to non-ZBNF	Method	Year	Source
Paddy	+	10%	CCE	2016-17	Mishra 2018
	-	-6%	Self-reported	2014-15	Koner and Laha 2020
	-	-7%	CCE	Rabi 2018-19	Galab et al. 2019b
	-	-8%	CCE	Kharif 2018-19	Galab et al. 2019a
Groundnut	+	28%	CCE	2016-17	Mishra 2018
	+	16%	CCE	Kharif 2018-19	Galab et al. 2019a
	+	3%	CCE	Rabi 2018-19	Galab et al. 2019b
Black gram	+	27%	CCE	2016-17	Mishra 2018
	+	19%	N/A	2017	Sarial 2019
	-	-11%	CCE	Rabi 2018-19	Galab et al. 2019b
Cotton	+	7%	CCE	Rabi 2018-19	Galab et al. 2019b
	+	6%	CCE	Kharif 2018-19	Galab et al. 2019a
Bengal gram	+	3%	CCE	Kharif 2018-19	Galab et al. 2019a
	-	-1%	CCE	Rabi 2018-19	Galab et al. 2019b
Red mash	+	13%	N/A	2017	Sarial 2019
Red gram	+	7%	CCE	Rabi 2018-19	Galab et al. 2019b
Mango	+	14%	CCE	Rabi 2018-19	Galab et al. 2019b

The sample size for each study listed is as follows: Galab et al. (2019a) – 1,365 farmers, Galab et al. (2019b) – 386 farmers, Koner and Laha (2020) – 50 farmers. Sample sizes for Mishra (2018) and Sarial (2019) were not reported. All studies were conducted in Andhra Pradesh except for Sarial (2019) and Koner and Laha (2020), which were conducted in Himachal Pradesh and West Bengal, respectively.

CCE – crop cutting experiment, N/A – Not available

See Table 7 on page 25 for data on additional crops.

Table 4: Changes in YIELD from multi-year studies

Crop	Location	+/-	Percent difference in yield relative to non-ZBNF 2016-17	2017-18	2018-19	Method	Year	Source
Banana	Andhra Pradesh	-	N/A	-20%	-17%	Self-reported	2016-19	Reddy et al. 2019
Cotton	Andhra Pradesh	-	-43%	-17%	-8%	Self-reported	2016-19	Reddy et al. 2019
Gram	Himachal Pradesh	+	25%	22%	N/A	N/A	2016-17	Sarial 2019
Groundnut	Andhra Pradesh	-	-33%	-21%	-7%	Self-reported	2016-19	Reddy et al. 2019
Lentil	Himachal Pradesh	+	44%	9%	N/A	N/A	2016-17	Sarial 2019
Paddy	Andhra Pradesh	-	-33%	-31%	-20%	Self-reported	2016-19	Reddy et al. 2019
	Himachal Pradesh	-	-1%	-1%	N/A	N/A	2016-17	Sarial 2019
Soybean	Himachal Pradesh	+	5%	9%	N/A	N/A	2016-17	Sarial 2019
Sunflower	Andhra Pradesh	-	-24%	-8%	-6%	Self-reported	2016-19	Reddy et al. 2019
Wheat	Himachal Pradesh	-	-9%	-2%	N/A	N/A	2016-17	Sarial 2019

Reddy et al. (2019) interviewed 4 to 5 individual farmers and held one focus group discussion for each crop. Sample size for Sarial (2019) was not reported.
N/A – Not available

Of the six total studies which evaluated the effects of ZBNF on paddy, five found decreases in yield relative to conventional production of 1, 6, 7, 8, and 33 percent, while one found an increase of 10 percent (see Tables 3 and 4 for details). Data for groundnut production were more positive, with three of four studies showing an increase in yield for ZBNF plots relative to non-ZBNF. Maize and black gram also exhibited yield increases relative to non-ZBNF production. It is also important to keep in mind that differences in climatic zone and district could change yield outcomes of ZBNF. For instance, Bharucha et al. (2020) found that yields of ZBNF crops were higher across all districts except for West Godavari, where yields were lower, likely due to waterlogging, which is a common phenomenon in the delta region (Bharucha et al. 2020). It is also important to note that total output for all crops under an intercropping system may improve even when yield from a single crop has decreased. Thus, future analyses should also evaluate system-wide yield impacts.

“... MORE ROBUST SYSTEM-WIDE, LONG-TERM DATA SHOULD BE COLLECTED ON ZBNF'S IMPACT ON YIELD BEFORE ANY BROAD CONCLUSIONS ARE DRAWN FROM EXISTING LITERATURE.”

In addition, these studies differ by methodology, with some collecting data from farmer surveys, and others conducting more comprehensive crop cutting experiments. For these reasons, more robust system-wide, long-term data should be collected on ZBNF's impact on yield before any broad conclusions are drawn from existing literature.

SOCIAL IMPLICATIONS

The social implications of ZBNF have not yet been empirically evaluated at any scale, so the evidence described in this section is minimal. The literature reviewed primarily discusses ZBNF's potential impacts on food security, gender equality, and migration.

Food and nutritional security. Several authors suggest ZBNF improves food and nutritional security (Galab et al. 2019a; Ghosh 2019; Gupta et al. 2020; Mishra 2018; Nene 2017). However, studies did not explicitly evaluate ZBNF's effects on food and nutrition security at the household nor state level. ZBNF could potentially improve household food and nutritional security through increased income and crop diversification, which has the potential to improve dietary diversity at the household and community level (Galab et al. 2019a; Gupta et al. 2020). According to Gupta et al. (2020), a larger share of ZBNF farmers produced fruits and vegetables as their main kharif crop compared to non-ZBNF farmers (Gupta et al. 2020). A CESS study reports ZBNF farmers who adopted the five-layer model cultivated a variety of leafy vegetables, gourds, chilies, bananas, mangoes, berries, and other produce (Galab et al. 2019a). Some ZBNF farmers produce these foods for their own consumption, but it is not clear what portion of their diet is met with their own production or whether this portion changes under ZBNF (Brown 2013; Galab et al. 2019a; Reddy et al. 2019). To improve household nutrition, RySS assigned Health and Nutrition Fellows to groups of five villages each, and in 2018, ZBNF implemented health and nutrition plans in 35 villages in Andhra Pradesh (Biswas 2020; RySS 2019). Studies have not explored how ZBNF shifts farmer household diets, increases the availability of nutritious food in the local market, or improves health due to a more nutritious diet.

"WHILE THE SHARE OF WOMEN IN THE ZBNF COHORT WAS ALMOST DOUBLE THAT OF NON-ZBNF, OVERALL WOMEN'S PARTICIPATION AS FARMERS IS STILL LOW."

ZBNF's impacts on food security at the state level are also uncertain. Crop diversification could shift the number of calories grown per unit area of cultivated land, which could have implications for the total amount of agricultural land needed to satisfy the demands for food and fibre in Andhra Pradesh. Furthermore, Smith et al. (2020) estimates that ZBNF only supplies 52 to 80 percent of the average nitrogen fertilizer applied in India, which could result in a yield penalty when yields are high and negatively impact food security (Smith et al. 2020). Farmers sometimes apply more ZBNF inputs (e.g., jeevamrutham) than prescribed, which could address concerns of limited nitrogen application, but long-term studies on yield and soil health are necessary to understand how variations of ZBNF impact yield and food security.

Gender equality. Some authors indicate that ZBNF improves gender equality, citing women's involvement in the scale-up of ZBNF (Gupta and Bose 2020; Tripathi et al. 2018). Women's self-help groups are critical to channeling funds for scaling up ZBNF at the village level. RySS aims to have equal representation of men and women leading clusters (i.e., groups of five villages each), which can encourage women's participation in the program (Tripathi et al. 2018). A report by CEEW suggests women's participation as leaders disseminating information about ZBNF and as entrepreneurs selling ZBNF inputs in shops can help improve their social status in their respective communities (Tripathi et al. 2018). As previously mentioned, in a CEEW survey of 581 farmers, 4 and 7 percent of non-ZBNF and ZBNF farmers, respectively, were women (Gupta et al. 2020). While the share of women in the ZBNF cohort was almost double that of non-ZBNF, overall women's participation as farmers is still low.

Land and livestock ownership are barriers to women's adoption of ZBNF (Kc et al. 2015). In addition, ZBNF's increased labor demand could have negative consequences for women who work as unpaid family laborers. In a study on organic farming in Odisha, researchers concluded women's health and food security improved under organic farming but their workload to prepare natural inputs increased, and women were excluded from technical training and decision-making (Altenbuchner et al. 2017). A similar study in Andhra Pradesh could identify gendered effects of ZBNF on women's participation, labor, health, and food security.

Youth interest and migration. One of RySS' objectives for ZBNF is to "reduce the migration of youth from villages and create reverse migration to villages" (RySS 2019). Studies on changes in migration due to ZBNF are not available, but there have been examples of reduced migration and reverse migration from urban centers to villages to practice ZBNF (ICRAF-RySS 2020; Khurana and Kumar 2020). There are instances of farmers returning to Anantapur from cities to practice ZBNF and of farmers deciding not to migrate from Anantapur for employment because costs significantly decreased under ZBNF (Khurana and Kumar 2020).

> "PROFITS FROM ZBNF COULD MAKE FARMING MORE ATTRACTIVE TO YOUNGER GENERATIONS THAT WOULD OTHERWISE MIGRATE FOR WORK."

Profits from ZBNF could make farming more attractive to younger generations that would otherwise migrate for work. Youth involvement as Natural Farming Fellows or champion farmers is important for the longevity of the program and potentially the agriculture sector. Future research should examine changes in short-term and long-term migration trends due to ZBNF, as well as changes in youth's perception of farming because of ZBNF.

CLIMATE AND ECOLOGICAL CONSIDERATIONS

This section summarizes ZBNF's climate adaptation and mitigation potential. While there are purported climate benefits, there were no studies to support or refute these claims at the time of writing. Climate resilience and ecological health have become central to the messaging of ZBNF (illustrated by RySS's website description of ZBNF at times as "Climate Resilient Zero Budget Natural Farming"). ZBNF claims to be more climate resilient through improved soil carbon stores, robust microbial communities, and improved water holding capacity in the soil. Gains in soil health are particularly important as conventional farming practices and land use change have resulted in significant soil degradation, and decreases in Indian GDP as a result (Bhattacharyya et al. 2015; Reddy 2003). ZBNF also claims to be a more environmentally friendly method of farming because it decreases fertilizer inputs (Gupta et al. 2020). Coupled with healthier soil structure, reduced chemical inputs has the potential to reduce sediment and fertilizer runoff, thereby reducing eutrophication and improving water quality. ZBNF also prescribes intercropping to increase crop diversity, which can in turn improve soil structure

and reduce pest pressure (Sharma et al. 2017). In addition, ZBNF encourages year-long soil coverage to hold soil in place and decrease sediment runoff (Reddy et al. 2019). Potential increases in water holding capacity and more responsible irrigation as prescribed by ZBNF may lead to a decrease in water use and increase in drought resilience, which is key as India looks to adapt to a changing monsoon season with more variable rainfall (ICRAF-RySS 2020). Some farmers from Vishakhapatnam reported that ZBNF paddy withstood cyclonic winds better than non-ZBNF paddy (Tripathi et al. 2018).

It remains to be seen what the impact of large scale ZBNF adoption would have on greenhouse gas emissions (GHGs), though a reduction in fuel consumption and a reduction in emissions associated with manufactured inputs, as well as a reduction in N_2O from reduced fertilizer use, figures to decrease overall agricultural emissions per cultivated unit of land. A comparative Life Cycle Analysis (LCA) done by CSTEP found that ZBNF systems use 50-60 percent less water, 45-70 percent less input energy, and emit 55-85 percent fewer GHG emissions (CSTEP 2020). While these findings are encouraging, it is worth noting that the LCA had a limited sample size (~120 farmers throughout 4 districts in Andhra Pradesh), did not consider soil carbon sequestration, and relied on farmer recall rather than formal data collection. It is also important to consider that in a scenario where ZBNF decreases yield, it is possible that unused marginal land may be converted to agriculture to make up for lost productivity, and ultimately increase net GHG emissions from land use change. If this were to happen, there could be a decrease of emissions per unit of cultivated land but an increase in the agricultural land base. Whether decreases in emissions per unit of land would be enough to offset increased emissions from land use change is an outstanding question, dependent on other factors including the existence and size of a yield penalty.

GAPS IN EVIDENCE

Through our review, we identified several key gaps in current literature on ZBNF. Many evaluations of ZBNF base their conclusions from qualitative surveys, focus groups, and farmer testimonials. While useful, additional participatory evaluations using both natural and social science methods would contribute to the evidence base on ZBNF and would be most helpful if designed to fill the gaps identified in this section. The gaps we identified exist on a spectrum, with some claims supported more robustly than others. Yield data from multi-year crop cutting experiments with corresponding soil sampling and household socioeconomic surveys carried out by independent organizations are particularly lacking, which leads to uncertainty in ZBNF's effects on yield, profitability, ecological health, and climate resilience. In addition, the generalizability of studies is difficult to determine, as climate is variable in different regions of Andhra Pradesh, farm size is often not taken into account when evaluating ZBNF impact, and ZBNF is not clearly or consistently defined across studies, limiting what existing research can tell us. As Andhra Pradesh scales up ZBNF, there is also a lack of multi-year studies, adding uncertainty to the effects of these farming practices. How ZBNF will change yield and soil health in the long term is an outstanding question, despite RySS aiming for full coverage by 2027. There are some comprehensive studies on financial outcomes, though without long-term studies there is concern that long-term economic penalties could lead to dis-adoption among farmers.

Data on ZBNF coverage and resource allocation for adoption are also lacking. Though RySS publishes their number of ZBNF-practicing farmers on their website, it is difficult to tell where those farmers are, how they farmed previously, or how they define ZBNF. Studies and farmer accounts of ZBNF yield and economic impacts have shown differences in outcomes based on scale of operation, making it more difficult to understand adoption data without knowing which, and at what scale, farmers are adopting. Geographical distribution of women self-help groups, Community Resource Persons, Natural Farming Fellows, Health and Nutrition Fellows, and champion farmers, and their outreach strategies have not been evaluated to our knowledge and are key to scaling up ZBNF. Further, data on allocation of resources are necessary to understand how farmers are financing their adoption of ZBNF. Spatial data on coverage and resource allocation are critical to designing large scale research studies with representative samples across the state and are important for future understanding of ZBNF.

“THE LACK OF DATA ON HOW FARMERS ARE CHANGING CROP PRODUCTION AND THEIR DIETS AS A RESULT OF ZBNF IS A MAJOR BARRIER TO UNDERSTANDING THE POTENTIAL THAT ZBNF HAS TO CHANGE FOOD SYSTEMS IN ANDHRA PRADESH AND INDIA MORE BROADLY”

Furthermore, there is a gap in data-driven reviews of how ZBNF will shift Andhra Pradesh’s foodscape. Uncertainty in yield data and lack of data on nutrition outcomes bring about key questions of how the number of calories grown per hectare and diet quality will be affected. Preliminary data primarily from single year studies show decreases in yield of ZBNF paddy relative to conventional agriculture (Galab et al. 2019b; Koner and Laha 2020; Reddy et al. 2019; Sarial 2019). This trend could be limited to the first few years after conversion or it could reduce overall yield in the long run, potentially leading to agricultural conversion of marginal lands, and releasing more greenhouse gases into the atmosphere. Evidence from focus groups has shown that ZBNF farmers tend to grow more vegetables than non-ZBNF farmers (Gupta et al. 2020), which could improve nutrition as well as increase or decrease total calorie production, depending on what farmers are switching their production from. The lack of data on how farmers are changing crop production and their diets as a result of ZBNF is a major barrier to understanding the potential that ZBNF has to change food systems in Andhra Pradesh and India more broadly.

Finally, data on the implications of ZBNF for women, landless workers, and youth are lacking. Data on changes in women’s and landless agricultural workers’ incomes and labor could provide insight into ZBNF’s impacts on more vulnerable groups. Rural-urban migration has far-reaching impacts for agriculture, including the feminization of the agricultural workforce (Sharma and Nayak 2019) and the absence of young farmers. Long-term studies of ZBNF’s impact on migration and youth’s perception of farming could clarify whether ZBNF and programs like it can revive farming as a desirable occupation.

Conclusion

Existing literature on farmer sentiment and well-being in India has illustrated a demand for an alternative to current agricultural practices. The high input systems which characterize Indian agriculture can lead to negative financial, environmental, and social outcomes, from which many farmers seek reprieve. Farmer suicides, outmigration, and soil degradation are all severe consequences from conventional farming which threaten food security and are tied to rural well-being in India. ZBNF addresses these issues by presenting an alternative to conventional agricultural practices and providing farmers with more autonomy and freedom from debt. While some early indicators of ZBNF's effect on finances and yield are positive, long-term and system-wide data must be collected to confirm these studies, and there remain gaps in literature concerning how ZBNF changes foodscapes, ecological health, and farmer well-being, including the well-being of women and landless laborers. In addition, further governmental support including funding for research, formal certification systems for ZBNF crops, tenant contract reform, and more targeted resource allocation to assist with the financial burden of the transition period could all prove helpful in scaling up ZBNF effectively.

"THOUGH MUCH OF THE EARLY DATA ON ZBNF ARE PROMISING, THE ABSENCE OF LONG-TERM STUDIES AND DEARTH OF FIELD RESEARCH IS A CONSIDERABLE GAP IN PUBLISHED LITERATURE AND NEEDS TO BE FURTHER EXAMINED IN ORDER TO MAKE INFORMED POLICY DECISIONS CONCERNING STATE-WIDE ADOPTION OF ZBNF."

Though much of the early data on ZBNF are promising, the absence of long-term studies and dearth of field research is a considerable gap in published literature and needs to be further examined in order to make informed policy decisions concerning state-wide adoption of ZBNF. Crop yield appears to be variable dependent on geography, research method, and sample size, which makes the data difficult to generalize. More comprehensive research which includes multi-year studies that consider farm scale and growing climate are necessary to better understand how ZBNF affects yield. Similarly, there are mixed data on financial outcomes (though they tend to be much more consistent than yield data) which warrant more research, particularly if some crops or geographies are shown to have more favorable outcomes than others. Finally, to our knowledge there are no peer-reviewed studies which examine how ZBNF changes soil composition, particularly in the long term. Understanding this is paramount to verifying the long-term viability and sustainability of ZBNF in India. Long-term, peer-reviewed studies to fill knowledge gaps on climate effects, gendered impacts, youth participation, migration impacts, and system-wide productivity and profitability are critical to informing sound policies concerning the state-wide scaling up of ZBNF. Without this information it is extremely difficult to ascertain if ZBNF should be applied state-wide or be targeted to specific farmers in certain areas.

Preliminary data suggest that ZBNF will not be a blanket solution that will achieve the same outcomes for everyone, and this is perhaps the most important consideration moving forward. Identifying the variables which are conducive to a successful ZBNF system is an important next step in the state-wide rollout of these practices. Given the goal of achieving 100 percent ZBNF coverage by 2027, these considerations, as well as a broader consideration of how ZBNF might change the profile of crops grown in Andhra Pradesh, should be addressed in order to make informed policy decisions that benefit farmers and advance food security.

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Economic and yield data for additional crops:

The tables in this section summarize net income, yield, and cost information for additional crops in literature reviewed.

Additional Information

Table 5: Changes in net income under ZBNF relative to non-ZBNF for ADDITIONAL CROPS

Crop	+/-	Percent difference in net income relative to non-ZBNF	Season/Year	Source
Banana	+	80%	Rabi 2018-19	Galab et al. 2019b
	-	-5%	N/A	Reddy et al. 2019
Green gram	+	35%	Rabi 2018-19	Galab et al. 2019b
Jowar	+	80%	Rabi 2018-19	Galab et al. 2019b
Maize	+	111%	Kharif 2018-19	Galab et al. 2019a
	+	13%	Rabi 2018-19	Galab et al. 2019b
Sesamum	+	23%	Rabi 2018-19	Galab et al. 2019b
Sugarcane	+	10%	Rabi 2018-19	Galab et al. 2019b
Sunflower	-	-8%	N/A	Reddy et al. 2019
Tomato	+	41%	Kharif 2018-19	Galab et al. 2019a
Rainfed crops	+	50%	Kharif 2017	Bharucha et al. 2020

The sample size for each study listed is as follows: Galab et al. (2019a) – 1,365 farmers, Galab et al. (2019b) – 386 farmers. Reddy et al. (2019) interviewed 4 to 5 individual farmers and held one focus group discussion for each crop. Bharucha et al. (2020) analyzed crop-cutting experiments on 1,356 plots.
N/A – Not available

Table 6: Changes in cultivation cost under ZBNF relative to non-ZBNF for ADDITIONAL CROPS

Crop	+/-	Percent difference in net income relative to non-ZBNF	Season/Year	Source
Banana	-	-0.4%	Rabi 2018-19	Galab et al. 2019b
	-	-33%	N/A	Reddy et al. 2019
Green gram	-	-17%	Rabi 2018-19	Galab et al. 2019b
Jowar	-	-29%	Rabi 2018-19	Galab et al. 2019b
Maize	-	-1%	Kharif 2018-19	Galab et al. 2019a
	-	-20%	Kharif 2019	Gupta et al. 2020
	-	-28%	Rabi 2018-19	Galab et al. 2019b
Sesamum	-	-3%	Rabi 2018-19	Galab et al. 2019b
Sugarcane	-	-2%	Rabi 2018-19	Galab et al. 2019b
Sunflower	-	-4%	N/A	Reddy et al. 2019
Tomato	-	-18%	Kharif 2018-19	Galab et al. 2019a
Rainfed crops	-	-24%	Kharif 2017	Bharucha et al. 2020

The sample size for each study listed is as follows: Galab et al. (2019a) – 1,365 farmers, Gupta et al. (2020) – 581 farmers, Galab et al. (2019b) – 386 farmers. Reddy et al. (2019) interviewed 4 to 5 individual farmers and held one focus group discussion for each crop. Bharucha et al. (2020) analyzed crop-cutting experiments on 1,356 plots.
N/A – Not available

Table 7: Changes in yield under ZBNF relative to non-ZBNF for ADDITIONAL CROPS

Crop	+/-	Percent difference in yield relative to non-ZBNF	Season/Year	Method	Source
Banana	-	-12%	CCE	Rabi 2018-19	Galab et al. 2019b
Cashew nut	+	29%	CCE	Rabi 2018-19	Galab et al. 2019b
Chilies	+	32%	CCE	2016-17	Mishra, 2018
	-	-8%	CCE	Rabi 2018-19	Galab et al. 2019b
Citrus	-	-15%	CCE	Rabi 2018-19	Galab et al. 2019b
Flowers	+	276%	CCE	Rabi 2018-19	Galab et al. 2019b
Green gram	-	-0.4%	CCE	Rabi 2018-19	Galab et al. 2019b
Jowar	-	-7%	Self-reported	Rabi 2018-19	Galab et al. 2019b
Maize	+	30%	CCE	Kharif 2018-19	Galab et al. 2019a
	+	11%	CCE	Rabi 2018-19	Galab et al. 2019b
	+	8%	CCE	2016-17	Mishra 2018
Ogla/phapra	-	-3%	N/A	2017	Sarial 2019
Ragi	-	-3%	CCE	Rabi 2018-19	Galab et al. 2019b
Ragi	-	-8%	N/A	2017	Sarial 2019
Sesamum	+	38%	CCE	Rabi 2018-19	Galab et al. 2019b
Sugarcane	+	22%	CCE	Rabi 2018-19	Galab et al. 2019b
Sunflower	+	11%	CCE	Rabi 2018-19	Galab et al. 2019b
Tomato	+	2%	CCE	Kharif 2018-19	Galab et al. 2019a
Rainfed crops	+	17%	CCE	Kharif 2017	Bharucha et al. 2020

The sample size for each study listed is as follows: Galab et al. (2019a) – 1,365 farmers, Galab et al. (2019b) – 386 farmers, Koner and Laha (2020) – 50 farmers. Reddy et al. (2019) interviewed 4 to 5 individual farmers and held one focus group discussion for each crop. Bharucha et al. (2020) analyzed crop-cutting experiments on 1,356 plots. Sample sizes for Mishra (2018) and Sarial (2019) were not reported. All studies were conducted in Andhra Pradesh except for Sarial (2019), which was conducted in Himachal Pradesh.
CCE – crop cutting experiment, N/A – Not available

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