CESS Monograph 57

An Assessment of Millet-Based Agro-Biodiversity Systems Enriched with A Mix of Modern and Traditional Ecological Packages

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Foreword

The Centre for Economic and Social Studies (CESS) was established in 1980 to undertake research in the field of economic and social development in India. The Centre recognizes that a comprehensive study of economic and social development issues requires an interdisciplinary approach and tries to involve researchers from various disciplines. The centre's focus has been on policy relevant research through empirical investigation with sound methodology. In keeping with the interests of the faculty, CESS has made important contributions to social science research in several areas; also reorienting research priorities taking into account topical and emerging issues.

Dissemination of research findings to fellow researchers and policy thinkers is an important dimension of policy relevant research which directly or indirectly contributes to policy formulation and evaluation of interventions. CESS has published several books, journal articles, working papers and monographs over the years. The monographs are basically research studies and project reports done at the Centre. They provide an opportunity for CESS faculty, visiting scholars and students to disseminate the research findings in an elaborate form.

The present monograph titled "An Assessment of Millet Based Agro-Biodiversity Systems Enriched with a mix of Modern and Traditional Ecological Packages" by E.Revathi, B.Suresh Reddy and P. Dayakar is an attempt to look at the various issues related to millet based mixed cropping systems and its economic and ecological significance. The field work of the study was facilitated by Deccan Development Society(DDS). Green Revolution model of agriculture from the 1960s eventually in cultivation of monocropping of non-food commercial crops thereby destroying agricultural bio-diversity in dryland zones. There is a loss of traditional knowledge and practices especially related to diverse dryland agriculture.

The present study tries to add new knowledge to the field of ecological agriculture and brings out major issues relevant to millet based biodiversity systems. Ecological significance of mixed cropping systems and soil fertility enhancing practices are clearly brought out in this study. The study highlights the economic and ecological benefits of millet based biodiversity systems in rainfed agriculture. The study also underlines the importance of crop and varietal diversity in dryland agriculture in the emerging climate change scenario.

This monograph provides valuable suggestions to policy makers from the empirical analysis. I hope it would be useful to the research community, policy makers, development practitioners and all those interested in the growth of eco-friendly agricultural cropping systems.

E.Revathi
Director, CESS

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Acknowledgements

The study would not have been possible without the contribution and cooperation of many individuals. First of all we would like to thank the women and men farmers, from socially disadvantaged sections for shaping our understanding and enlightening us about the issues related to environment friendly agriculture and the interconnectedness of various elements in rainfed farming.

We thank Prof.Dilip Nachne, Chairman, CESS for the support and encouragement during our research work. Our heartfelt thanks are due to many people working with our research partner Deccan Development Society(DDS), Pastapur,Telangana. Firstly, we would like to thank late Sri. P.V.Satheesh, Director, DDS for collaborating with CESS on this research study and extending the financial support. His passionate support for the study helped us to complete it successfully. Megha Choppari, research intern at DDS assisted in coordinating the field work for the study. The smooth conduct of this study could not have been possible without the committed support of Giridhar, Joint Director, DDS. Field staff of DDS has supported us during the field survey. We thank the DDS staff fraternity for the support received. We also thank Dr.Anjaneyulu, Rajkumar and Dastagiri from CESS for support received in curating the data.

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Hyderabad, February 2024

E.Revathi
B.Suresh Reddy
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Chapter 1
Introduction and Motivation

1.1. Introduction

Agriculture plays a significant role in the economy of India and constitutes the primary source of food, income, and employment to its rural populations. As per the World Bank report (2019), India is still largely dependent on the rural economy, and agriculture continues to be the mainstay of the largest population in the country according to the Fifth Annual Employment-Unemployment Survey of the Ministry of Labor and Employment. The share of agriculture in national income has declined from 56.5 percent in 1950-51 to 39.6 percent in 1980-81, 26.3 percent in 2001-02, and a mere 13.9 percent in 2013-14 at 2004-05 prices. Its share has risen to 18.8 percent in 2021-22 at 2011-12 prices, according to the new national income series released by the Central Statistics Office (Kapila 2022-23). The sector has witnessed robust growth in the past two years, with a growth rate of 3.6 percent in 2020-21 and 3.9 percent in 2021-22. In *Schultz's* view, "agriculture is important for economic growth because it guarantees subsistence for society without which growth is not possible in the first place. This early view on the role of agriculture in economics also matched the empirical observation made by Kuznets (1966) that the importance of the agricultural sector declines with economic development." (Dethier J., & Effenberger, 2012, p. 178). In addition to labor and food supply, agriculture plays an active role in economic growth through significant production and consumption linkages. For example, agriculture provides raw materials to other allied sectors` production. On the consumption side, higher agriculture productivity can increase the income of the rural population, thereby creating demand for domestically produced industrial output. These linkage effects increase employment opportunities in the rural allied sector, indirectly generating rural income. The average Indian household spends about 45% of its expenditure on food. However, agriculture in India as it stands today will certainly face a challenge to feed its entire population, a situation that is compounded by climate change and land degradation. This issue becomes more severe with the increasing urbanization scenario in the country. Further, as per capita income increases, there will be more months of feed and more demand for high-value agricultural products like fish, dairy, meat, fruits, and vegetables (OECD/FAO, 2019). One can also witness that people consume more nutritious food at rising income levels than starchy staple food.

Further, agricultural goods can be exported to earn foreign exchange to import capital goods. Growth and higher productivity in the agricultural sector can contribute to overall economic growth by releasing labor and capital to other economic sectors. Singer (1979) further stressed the importance of such linkages. The fact that there are critical linkages between the traditional and modern sectors in developing countries makes agricultural growth a vital instrument for decreasing poverty. The contribution to poverty reduction occurs directly through the effects of agricultural growth on farm employment and profitability. It indirectly increases agricultural output-induced job creation in upstream and downstream non-farm sectors in response to higher domestic demand. The empirical investigation of the relationship between the agricultural sector and economic growth has a long history. Recently, Timmer (2002) used a panel of 65 developing countries from 1960 – 1985 to show a positive correlation between growth in agricultural GDP and its lagged values and non-agricultural GDP growth. Similarly, Grabowksi (2007) established a positive relation between different agricultural productivity measures and average real GDP per capita growth over 1960 – 1995 for a cross-section of countries.

The recent empirical findings highlight that the effect of agricultural progress on poverty alleviation is highly positive. Mellor (2001) argues that it is not economic growth in general that reduces poverty in developing countries but the direct and indirect effects of growth in agriculture. In their study of poverty in India over 35 years, Datt and Ravallion (1996, 1998) find that higher farm productivity reduces absolute and relative poverty. This is partly due to a direct channel of higher household income operating in the short run and partly due to indirect channels, such as higher wages and lower food prices in the longer run. This strengthens the argument for supporting agricultural growth.

Similarly, Loayza and Raddatz (2010) show for a cross-section of developing countries that growth in more labor-intensive sectors, such as agriculture, has a more considerable impact on poverty reduction than less labor-intensive activities. Christiansen and Demery (2007) estimate that 1 percent per capita agricultural growth reduces poverty by 1.6 times more than industrial growth and three times more than growth in the service sector. In a recent study by the World Bank, a target has been set to feed a projected 9.7 billion people by 2050. Agriculture sector growth is more effective than other sectors. Analyses in 2016 found that 65 percent of poor working adults made a living through agriculture (World Bank, 2020). Hence, agricultural growth is central to helping people experiencing poverty in developing countries.

1.2. Agriculture under Climate Scenarios in India

In the recent past, empirical works acknowledged a significant influence of climatic stresses on the agriculture sector, especially extreme climate events such as droughts, heat waves, and floods. Climate change is projected to cause significant negative impacts on agriculture in India overall, and its impact varies across seasons and regions. Further, according to the Economic Survey (2018), the loss of farm revenue due to extreme climate events is around 12% for Kharif and 6% for Rabi crops, and more impacts on rainfed crops in the country. Temperature fluctuations are responsible for 4% of Kharif and 5% of Rabi seasons and vary across regions and crops (Prasanna, 2014; The Economic Survey, 2018; Chand Ramesh, 2022). The impact of climate change on crop yields may touch up to 60% by the end of the century, depending on crop type, region, and future climate scenarios (Rosenzweig *et al.,* 2014; Challinor *et al.,* 2014; Ray & Chowdhury, 2015). Estimations report that major cereals (i.e., *rice, wheat, and maize*) are more sensitive to climate change (Birthal *et al.,* 2015; Barnwal& Kotani, 2013; Gupta *et al.,* 2014), leading to food supply imbalance and rising hunger and malnourishment (Saxena *et al.,* 2018).

Empirical studies indicated different crop yield losses depending upon the method and climate change scenario used for impact assessments- yield losses for rice are 12%, for wheat 9%, maize 10%, for mustard 12%, and potato 13% by 2040 under RCP 4.5 scenarios compared to 2000-07 mean values (Chand Ramesh, 2022; Naresh Kumar *et al.,* 2013, 2014a, 2015, 2019). Regional-level empirical studies highlight that climate impacts differ across crops and seasons. Maize yields are severely affected by an increase in minimum temperature in Telangana (Rajeshwer & Dayakar, 2023). Pearl millet yields are projected to reduce in Maharashtra while they increase by 2050 based on different future scenarios (Piara Singh *et al.,* 2017). Moreover, grain quality may differ based on future climate scenario projections in India. For instance, wheat grain protein is projected to reduce by about 1.1% in climate events with high and low input conditions. In addition, these include minerals which are also reduced in many crops (Chand Ramesh, 2022; Porter *et al.,* 2014).

1.3. Agriculture Transformation after Post Green Revolution

Small and marginal farmers hold about 87% of the total operational land in India; of these, 69% belongs to only marginal farmers with less than one hectare of land, highlighting that Indian agriculture is dominated by small-holding farmers. Moreover, increasing fragmentation of land is another problem for Indian agriculture. The average land holding size has come down continuously from 2.28 hectares in 1970-71 to 1.08

hectors in 2015-16 period. This complicates the adoption of new technologies and adversely impacts both farm productivity and farmers' income (NITI Aayog, 2016). The availability of water for irrigation of the crops is one of the significant factors in choosing cropping patterns in the country. Empirical studies acknowledge that cropping patterns, cropping intensity, and crop diversification are significantly influenced by irrigation facilities across the globe and in India. In India, cropping has improved gradually from 123.1% in 1980-81 to 143.6% in the 2016-17 period in the country (DES, 2017). The state-wise cropping intensity shows a significant variation. The highest intensity is in Punjab (189%), followed by Haryana (184.4%), West Bengal (183%), and Uttar Pradesh (163%). Medium cropping intensity can be seen in Madhya Pradesh (159%), Bihar (145%), Rajasthan (143%) and Maharashtra (141.6%). States including Andhra Pradesh, Karnataka, Telangana, and Tamil Nadu show comparatively less cropping intensity. Further, post-green revolution fertilizers have taken a significant role in crop productivity in the country over the years. Overall, fertilizer consumption (in terms of NPK) increased significantly from 2.17kg/ha in 1961-62 to 134kg/ha in 2018-19. However, this is different at sub-national and disaggregated levels. Among the central states, the per hectare consumption is the highest in Telangana (262 kg), followed by Bihar (216 kg), Punjab (213 kg), Haryana (210 kg), Andhra Pradesh (203 kg), Uttar Pradesh (178 kg), West Bengal (160 kg) and Tamil Nadu (153.5 kg). The remaining States' fertilizer consumption is lower than the all-India average. On the other hand, with rising incomes, people's consumption patterns shift towards high-value products. According to the NSSO survey report (2013), the average Indian household spends about 45% of its total monthly income on food expenditure. At the same time the data reveals a sharp decline in the share of monthly expenditure on staples in rural and urban areas across the country- from 41% to 10.08% in 1972-73 to 23.4% to 6.6% in 2011-12 periods in rural and urban areas, respectively. Therefore, the agricultural system needs to respond by producing more high-value and nutritious agricultural products. Crop choice is mainly based on soil type, rainfall, climate, technology, policies, and the existing socio-economic situation of the farming communities.

Indian agriculture is often discussed as the Green Revolution with its mixed record of successes and failures. Nevertheless, what most Indian farmers (over 60 percent) practice is rainfed agriculture, which is a farming system, entirely different from that in irrigated areas. Major cereals (*i.e.,* paddy, maize, and wheat), minor cereals (*i.e.,* sorghum, finger millet, pearl millet, and minor millets), pulses (*i.e.,* chickpea, pigeon pea, minor pulses), oil seeds (*i.e.,* groundnut, sesamum, rapeseed, safflower, castor, linseed, sunflower, soybean), commercial crops (*i.e.,* cotton and sugarcane), fruits and vegetables are dominating crops, cover more than 90 percent of the total cultivated area in the country (ICRISAT-TCI, 2017).

The data reveals that the agriculture cropping patterns and trends indicate that farmers in India tend to move towards conventional[1] and mono-cropping practices across the state, except for some patches of rain-fed regions in the country. Higher expectation from agriculture is the main reason for this transformation in India (Chand Ramesh, 2022; Majhi & Kumar, 2018).

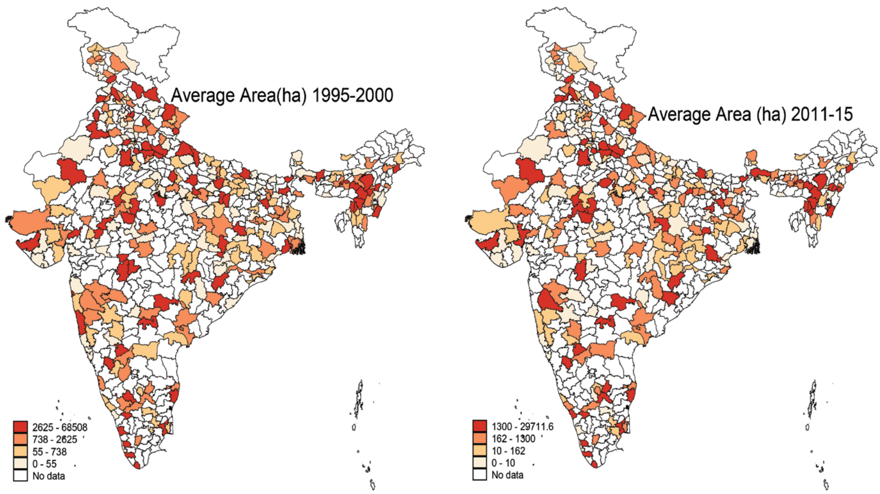

Figure 1. 1: Spatial Distribution of Area Under Millets Cultivation in India
Source: Authors own calculations based on Crop Production Statistics, GoI

Initially, food grans had occupied around 70% of the total grass-cropped area in 1982-83 but gradually reduced to around 60% in 2016-17, indicating that farmers are moving towards more commercial crops such as cotton, oilseeds, horticultural crops, and spices (Majhi & Kumar, 2018). On the other hand, the net sown area in the cultivation of millet-based agriculture across the country has declined significantly over the decades. Other cereals in cultivation have increased due to various technological, input, and output market policies (Dayakar, 2021). Further, the data reveals that the area in cultivation (especially small millets) declined from 3725 thousand hectares to 2422 thousand hectares from 1995-2000 to 2011-2017. This suggests that farmers have neglected millets over the decades due to the country's lack of technological development and market and price policies (Pingili *et al.,* 2017). Figure 1.1 shows that the spatial distribution of the area under millets cultivation (especially small millets) had declined

1 *Conventional agricultural practices* are defined as cultivating mainstream crops like paddy, maize, cotton, sugarcane, and chili.

across districts in India during the 1995-2015 period. The cultivated area under minor millets is distributed mainly across the states of Madhya Pradesh, Chhattisgarh, Tamil Nadu, Karnataka, Orissa, Maharashtra, Rajasthan, Uttar Pradesh, Andhra Pradesh, and Uttarakhand states in India. However, the data reveals those states such as Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Uttarakhand, and Rajasthan rank top regarding crop yields among millet-cultivated states in India. Despite their agronomic, climatic, and nutritional benefits, millet production has shown significantly negative growth over decades in India. Input and market policies (especially minimum support price) are pivotal in agricultural production. Post-Green Revolution, the Government's agricultural policies are biased toward staple crops, inadvertently crowding out traditional millets (Pingili *et al.,* 2017). Over the years, access to irrigation, improved mechanization, and increased fertilizer consumption per acre have resulted in agricultural intensification in the country. It is worthwhile also noting that over-agricultural intensification may have adverse impacts on natural resources, the environment, soil degradation, depletion of groundwater, and greenhouse gas (GHG) emissions (Chand Ramesh, 2022; Aditya *et al.,* 2020; Xie *et al.,* 2019). According to Central Ground Water Board (CGWB) data, Punjab, Haryana, Uttar Pradesh, Rajasthan, Gujarat, Karnataka, Andhra Pradesh, Telangana, and Tamil Nadu states have been facing poor quality of groundwater due to exploitation over the years. On the other hand, the imbalanced consumption of micronutrients, including sulfur, zinc, iron, and manganese, that characterizes poor groundwater quality adversely affects human health.

1.3.1. Agricultural status in Telangana

The total geographical area of the Telangana State is 112.07 lakh hectares, of which the area under cultivation is 49.61 lakh hectares (43.20 percent). The net area irrigated in the state is 21.84 lakh hectares in 2019-20, and the remaining 24.21 lakh hectares are under dryland cultivation (DES, 2020). Out of the cultivated areas, 52.17% are under dryland cultivation. In the last 50 years, a significant shift in the irrigation pattern in Telangana has made it more costly for the farmers, highly uncertain and unsustainable (Rao, 2014). It is against this backdrop that focusing on dryland agriculture assumes immense importance. Agricultural cultivation practices in Telangana are like all of India; farmers are moving towards significant cereals, commercial crops, and mono-cropping practices. Major cereals, minor cereals, pulses, oilseeds, commercial crops, fruits, and vegetables dominate more than 80% of the total cultivated area in Telangana (ICRISAT-TCI, 2017). However, in cultivation, significant cereals, commercial crops, fruits, and vegetable areas have shown a distinct increased from 1966 to 2017 (ICRISAT-TCI, 2017) while pulses, oilseeds, and millets area has shown a significant decrease.

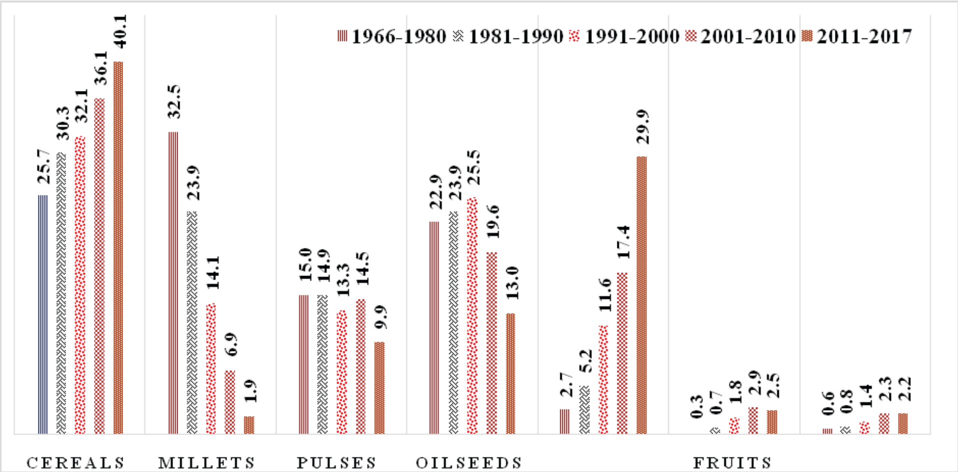

Figure 1. 2: Crop wise Area Cultivation in Telangana during 1966-2017 Period (in % of Total Cropped Area)
Source: Data extracted from ICRISAT-TCI

The area in cultivation of significant cereals, commercial crops, fruits, and vegetables has increased from 141, 15, 2, and 3 thousand hectares in 1966-1980 to 256, 193, 15, and 11 thousand hectares in 2011-2017, respectively. Meanwhile, the area in cultivation under millets, pulses, and oilseeds have decreased from 203, 86, and 161 thousand hectares each, in 1966-1980 to 12, 63, and 93 thousand hectares each, during the 2011-2017 period, respectively. However, the area under oilseed cultivation increased from 1966-1990 to 1991-2000 and subsequently declined continuously. In terms of percentages (i.e., in area cultivated to total cultivated area), cereals, commercial crops, fruits and vegetables area in cultivation has increased from 25.7%, 2.7%, 0.3% and 0.6% of total cultivated area in 1966-1980 to 40.1%, 29.9%, 2.5% and 2.2% in 2011-17 periods, respectively. Data reveals that growth in area under cultivation, of major cereals and commercial crops has significantly increased compared to other crops. However, growth in the area under millets, pulses, and oilseeds in cultivation has shown a decline over the same period.

1.4. Recent Developments in Agriculture

Based on the climate change and soil quality projections there is need to transform agriculture sector for sustainable agricultural growth. Hence, empirical studies advocate alternative agricultural practices in the country, especially rainfed dominated regions of the country. NITI Aayog (2020) emphasizes that agroecology and natural farming has potential to tackle future problems. Moreover, the scientific communities believe that millet-based agriculture is a prominent solution to climatic, soil degradation and people's nutrition problems, especially in rain fed areas. Access to technology and extension services is a major problem hindering the adoption of millet-based agriculture systems in the country. Against this background, the present study tries to understand two questions- 1) Do organic inputs have any impact on millet-based agriculture systems revenues? 2) Do institutions play any role in agricultural outcomes in the context of millets in Telangana.

Deccan Development Society (DDS)[2] has taken up Swasamudra farming, an initiative to double the farmers' income in one agricultural season in rainfed lands by encouraging the use of a mix of modern and traditional ecological packages (consisting of Farmyard Manure, Mycorrhizha, Panchagavya, Vermiwash and Beejamrutham). In this context, the current study is "An Assessment of Millet based Agro-Biodiversity Systems enriched with a mix of modern and traditional ecological packages" in Zaheerabad region of Sanga Reddy District in Telangana State.

1.5. Policy framework

Several policies have been formulated and put in place recognizing the importance of rainfed agriculture and focusing on building nutritional security by intensifying the cultivation of millets. Some of the salient policies are as follows: National Policy for farmers (2007) acknowledged the need for strengthening extension services and expanding food security baskets to include nutritious crops like bajra, jowar, ragi and millets which are mostly grown in dry land areas. It has highlighted the role of NRAA (National Rain fed Area Authority) in forging symbiotic interactions and striking convergence with other initiatives and programs to promote water use efficiency and water conservation and provide technical support in drought prone areas.

National Water Policy (2008) has laid emphasis on watershed management and water conservation as a strategy for development of rainfed areas. Further, to mitigate risk in the agriculture sector, a scheme "Pradhan Mantri Fasal Bima Yojana" (PMFBY) was launched in 2016. Schemes such as formation & promotion of 10,000 FPOs & instituting the Agriculture Infrastructure Fund have also been launched recently to

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2 The Deccan Development Society (hereafter DDS) has been playing a significant role in farming communities in the study area. The DDS is a three and half decade old grassroots organization working in about 75 villages with women's groups called *Sanghams* (*voluntary village level associations of the poor*) in Sangareddy District of Telangana, India. The 5000 women members of the Society represent the poorest of the poor in their village communities. Most of them are Dalits, the lowest group in the Indian caste hierarchy. DDS supports farmers who come under its purview in terms of input subsidy, extension, technical services, promotion of organic agricultural practices, and offers minimum support prices to farmers who do not get support price from Government for their produce.

benefit the sector. National Forest Policy (1988) focuses on enhancing land cover and rehabilitating degraded ecosystem with the objective of conservation and management of natural resources. The Doubling of Farmers Income (DFI) Committee suggested crop diversification for water use efficiency and sustainability of soil health (DFI Committee Report 2017). The Crop Diversification Programme sought to shift the area under paddy cultivation to crops requiring less water like oilseeds, pulses, traditional cereals or nutri-cereals. The above policy interventions point towards the importance of rain fed agriculture in general and millet cultivation in ensuring nutrition security.

1.6. Structure of the study Chapters

The report is organized into four chapters to address stated objectives. Chapter 2 discusses the method employed for data sample collection. The chapter then goes on to provide details of the study including the study location and data collection strategy. Chapter 3 seeks to document the characteristics of sample villages and the farming practices across cropping systems. Economics of millet-based agriculture system in the study area and its comparison estimations are provided in Chapter 4. Finally in Chapter 5, the findings are summed up along with the policy implications of the findings and draws conclusions.

Chapter 2
Objectives of the Study and Sample Design

2.1. Introduction

Chapter one highlighted the significance of millet-based agriculture systems in view of the impending uncertain climate conditions looming in the near future. As seen in the previous section, the backbone of rural economy in Telangana is agriculture. The sector which contributed around 15% to gross state domestic value (GSDV) of Telangana, has grown by 20.9%, which is one of the highest rates in India and significantly higher than India's gross value added (GVA) agriculture growth of 3% (GoT, 2021). The agricultural sector not only ensures food security but provides livelihoods to nearly 55.5% of the state workforce which depends on agriculture and its allied sectors (Census, 2011). About 55.54 lakh farm holdings exist in the state, with an average land-holding size of 1.12 hectares (ha). The large size of agricultural land holdings requires focus on agriculture growth to promote inclusive growth, enhancement of rural incomes, and sustained food security (Roehlano, 2013). However, the State is also largely dependent on rain-fed agriculture which is the dominant mode of cultivation where agriculture production depends upon distributional rainfall. South-West Monsoon (79%) is spread over the period from June to September, North-East Monsoon (14%) from October to December and the rest of 7% rainfall is received during the winter and summer months. Telangana receives a normal rainfall of 906 mm in a year (GoT, 2020).

The state has limited irrigation facilities with tube wells, dug wells, tanks and other sources being the main sources of irrigation, contributing 59%, 20%, 10%, 9%, and 2% respectively to the irrigated area in Telangana (ICRISAT-TCI, 2015). Marginal farmers are dominant in total operational holdings, constituting nearly 62% (GoT, 2017). As highlighted in Chapter 1 cereals, millets, pulses, oil seeds, cotton, sugarcane, fruits, and vegetables are dominating crops in Telangana[3]. However, cereals, commercial crops, fruits, and vegetables area in cultivation have significantly increased during the period from 1966 to 2017 (Fig. 2.1), whereas pulses, oilseeds and millets cultivated area has significantly decreased during the same period.

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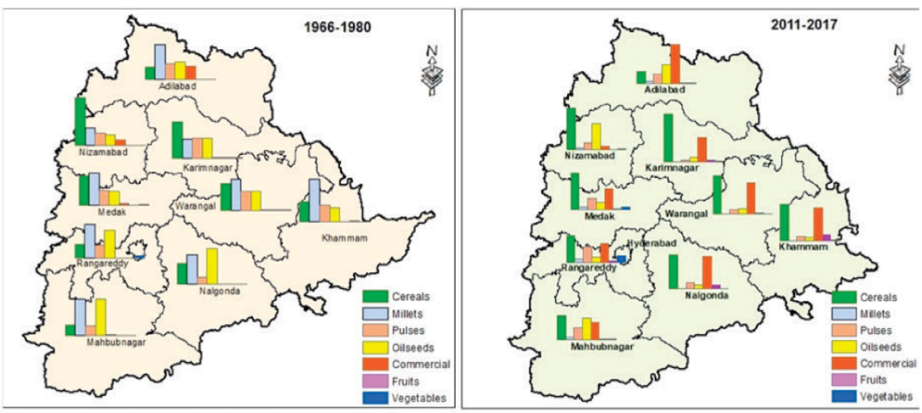
3 These crops cover more than 90 percent of the total cultivated area in Telangana (ICRISAT-TCI, 2015).

Figure 2.1 shows that the distribution of cropping pattern significantly changed across districts in Telangana over the years. Especially, the growth of cereals, fruits, commercial crops and vegetables area in terms of cultivation percentages to total cropped area, has increased across districts except Nizamabad district from 1966-1980 to 2011-2017 period. At same time, area under millets cultivation has touched more than 90% across the districts in Telangana. Pulses have shown a negative growth rate ranging from 30% to 88% except Nalgonda district where it has shown a growth rate of 0.4%. On the other hand, the rate of change in the area under pulses cultivation has declined in Rangareddy, Nalgonda, Mahbubnagar, Khammam, Warangal, and Medak districts while in Nizamabad and Adilabad districts, area in cultivation has increased during the same time intervals.



District	Cereals	Millets	Pulses	Oilseeds	Commercial	Fruits	Vegetables
Adilabad	13.1	36.8	16.7	18.3	14.3	0.1	0
Hyderabad	0	0	0	0	0	0	0
Karimnagar	38.2	19.7	20.6	20.8	0.2	0.3	0.2
Khammam	21.1	44.5	17.4	15	0.1	1.2	0.1
Mahabubnagar	11	38.4	10.5	39	0.8	0.1	0.2
Medak	31.4	34.3	16.2	14.7	2	0.2	0.7
Nalgonda	22.3	31.9	7.5	37.9	0.1	0.1	0.1
Nizamabad	50.9	18.3	12.6	11.1	6	0.2	0.5
Rangareddy	15	36.4	14.2	29.6	0.4	0.3	3.1
Warangal	27.8	32.4	19.3	19.7	0.3	0.2	0.2

District	Cereals	Millets	Pulses	Oilseeds	Commercial	Fruits	Vegetables
Adilabad	14.9	3.2	10.8	22.3	46.9	0.7	1.1
Hyderabad	0	0	0	0	0	0	0
Karimnagar	58.1	0.5	2.9	5.6	29.8	2.4	0.9
Khammam	43.4	0.2	5.6	3.6	39.3	7	0.7
Mahabubnagar	29.6	3.4	15.4	26.6	21.5	1.5	1.9
Medak	43.8	2.9	14	8.7	25.7	1.2	3.6
Nalgonda	41.5	0.5	7.6	4.9	39.7	5	0.6
Nizamabad	50	1.7	7.8	31.3	4.4	0.3	1.4
Rangareddy	32.7	4.4	19.4	6.9	23.3	3	9
Warangal	46.8	0.3	5.3	7	38	1.7	0.9

Figure 2. 1: Average Percentage of Crop Wise Area to Total Cropped Area from 1966-1980 to 2011-2017
Source: *Extracted from ICRISAT-TCI data*

Climatic conditions, pests, monsoon behavior, and farming practices are seen to be largely responsible for changes in cropping patterns, net area sown, and productivity (GoT, 2017). Moreover, technological changes, access to irrigation and input and market prices (especially, minimum support price) have played a key role in agricultural production. Post green revolution, the Government agricultural policies have shown a definitive biased towards staple crops, inadvertently resulted in crowding out many crops including oilseeds, pulses, and millets (Pingili *et al.,* 2017).

2.1.1. Significance of Diversified Agriculture in Selected Area

Climate models predict that frequency of extreme climatic events like droughts, extreme temperature, and floods increase in future and adversely affect the agriculture sector, especially in rainfed areas. Nevertheless, diversity is a cushion from production loss arising out of extreme climate which also influences the local prices and acts as a natural insurance against such uncertain climate conditions (Pingali, 1995). Sangareddy district of Telangana falls under medium diversified agricultural zone indexed with 0.77 (GoT, 2021; Vani, 2017). Cereals, commercial crops, pulses, and millets are dominating crops in this district. However, as indicated in Fig. 2.2, farmers are shifting from millet-based agriculture to cereals and other commercial cropping systems in the erstwhile district of Medak[4] in Telangana. Technological change, climatic factors, input and market prices are responsible for changing cropping patterns over the years and hence, farmers are drawn towards conventional crops. Given the predominance of agriculture in the State, the present study tries to explore the comparability of millet-based agriculture systems and conventional agricultural practices, and their returns.

The present Chapter offers a detailed description of field study- including study location, data collection methodology and the socio-economic characteristics of study area. The Chapter looks at the study location, sample design, survey instrument and questions Section 2.2, followed by a detailed description of farm characteristics and socio-economic variables, village profiles and cropping patterns in Section 2.3. Section 2.4 offers the conclusion of the Chapter.

2.2. Field Study Location

Zaheerabad area is a part of Sangareddy district of Telangana state in India. The survey area lies approximately 120 kilometers northwest of the state capital Hyderabad. Name of the area coined by a Paigah noble called Mahammad Zaheeruddin Khan. The selected area falls within the region highly vulnerable to drought with an annual average rainfall of 600 mm, over 80% of which received during the monsoon season from June to September (GoT, 2020). The study area is dominated with rainfed agriculture and millets, cereals, pulses and maize and cotton are main crops grown in Kharif (*Vanakalam*) season. However, as detailed earlier, the cropping pattern is heading towards monocropping/commercial cropping systems from mixed crops over the years due to assorted reasons.

4 Sangareddy district was carved out from erstwhile Medak district in 2016.

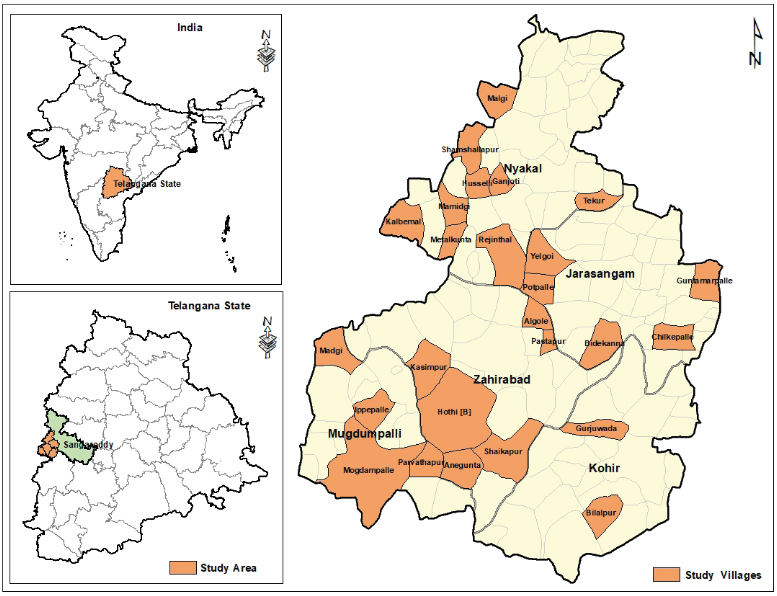


Figure 2. 2: Location of Study and Villages in Telangana State

The Deccan Development Society (hereafter DDS) has been playing a significant role in farming communities in the study areas. The DDS is a three and half decade old grassroots organization working in about 75 villages with women's groups called *Sanghams* (*voluntary village level associations of the poor*) in Sangareddy District of Telangana. The 5000 women members of the Society represent the poorest of the poor in their village communities. Most of them are Dalits, the lowest group in the Indian Caste hierarchy. The Society has a vision of consolidating these village groups into vibrant organs of primary local governance and federate them into a strong pressure lobby for women, the poor and Dalits. A host of continuing dialogues, debates, educational and other activities with the people, facilitated by the Society, try to translate this vision into reality.

The programs initiated by the Society have evolved over the years into a strong political force for rural women. What started off with the intention of ensuring the simple sustenance needs to the group (*i.e.,* Sangham) members has become a tool of empowerment for them to address larger issues of food security, natural resource enhancement, education, and health needs of the region. The conscious integration of various activities in the Society has helped to retrieve women's natural leadership positions in their communities, and to fight the problem of lack of access and control over their own resources. These activities, alongside ensuring earth care, are also resulting in human care by giving the women a new-found dignity and profile in their village communities (DDS, http://www.ddsindia.com/www/default.asp[5]).

2.2.1. Data Sampling

Purposive sampling method was followed to select the study mandals and villages, to account for wide variations across villages in terms of crops and socio-economic heterogeneity. The study was carried out in 34 villages from five mandals of Zaheerabad region **(Fig.2.3)** The data used in the study came from household survey of 1094 farmers, categorized into four groups viz., SSS[6], non-SSS DDS farmers, non-DDS millet farmers, non-DDS, and non-millet farmers (Table 2.1).

Table 2.1: Category wise sample size across villages

Mandal	Village	Category	Selected Sample Size
Mugdhumpalli	Parvathapur	DDS[7] Millet & Non-DDS Millet	36
	Jadimalkapur	SSS & Non-DDS Millet	44
	Jamugaibod Thanda	SSS	58
	Upparapalli Thanda	SSS	49
	Ippapalli	Non-DDS Millet	30
Nalkal	Motalkunta	Non-DDS Millet & Non-Millet	29
	Mamidigi	Non-Millet	20
	Kalbemal	Non-Millet	17
	Regithal	SSS & Non-Millet	55
	Tekur	SSS & Non-DDS Millet	48
	Shamshallapur	SSS & Non-DDS Millet	62
	Gunjoti	SSS	17
	Huselli	SSS	20
	Malgi	SSS	31
Zahirabad	Pastapur	DDS Millet	5
	Algole	Non- Millet	15
	Khasimpur	SSS & Non- Millet	30
	Lachanayak Thanda	SSS& Non-DDS Millet	65

5 Accessed on 27th January 2022.

6 SSS defines as *SwasamruddhaSamudayalaSankalpam Farmers*, which consist of five farm-level inputs/methods including *Mycorrhiza, Panchgavya, Bheejamrutham, Vermivash and Samrudhi Yeruvu* to improve soil fertility and pest management mechanism.

7 Sangam refers to DDS Sangam farmer or farmers who are associated with DDS.

Mandal	Village	Category	Selected Sample Size
	Arjunnayak Thanda	SSS & Non-DDS Millet	65
	Jeedigadda Thanda	SSS & Non-DDS Millet	50
	Jammala Thanda	Non-DDS Millet	11
	Shaikapur Thanda	SSS, DDS Millet & Non-DDS Millet	43
	Shaikapur	SSS	30
	Mood Thanda	SSS	21
Jarasamgam	Algoyi	SSS, DDS Millet & Non-DDS Millet	21
	Potpalli	SSS, DDS Millet & No- Millet	20
	Bidakanne	SSS, Non-DDS Millet, and No – Millet	55
	Chilkapalli	SSS	21
Kohir	Madri	Non- Millet	19
	Gurujwada	Non- Millet	17
	Gotigaripalli	SSS, Non-DDS Millet, and No – Millet	60
	Bilalpur	SSS & Non-DDS Millet	30

Source: *Author's own calculations based on field study data*

The survey was conducted during July 2020 to March 2021. The DDS has provided SSS to around 600 farmers across villages to improve crop yields.

Figure 2. 3 Research Investigators Training at DDS Krishi Vigyan Kendra, Zaheerabad

We have covered all SSS DDS-Sangham farmers, sample of non-SSS Sangham farmers are 84, non-Sangham Millet farmers are 217 and 176 non-Sangham and non-Millet farmers across 20 villages to get heterogeneity. In each village, the list of households has been compiled from agricultural department data sets and a simple random sampling approach has been adapted to identify the households for survey. in addition to the Survey several focus group discussions (FGD) were conducted with different categories of sample farmers in some of the study villages to capture the issues in-depth in the study area.

2.2.2. Survey Questions

The questionnaire canvassed during the field survey had a total of twenty blocks. The first three blocks were devoted to the identification data- of the area sampled, the respondent's family and socio-economic status including agricultural amenities.

Blocks 4, 5, and 6, were devoted to gathering information on land holding, plot-level characteristics, crops pattern during Kharif 2020 period. Questions related to the cultivation costs are covered from block 7 to block 9 while those related to source of agricultural credit feature in block 10. Crop-wise output information is collected in blocks 11 to 13 and 14 information collected details on livestock. Information on source of agricultural information for crop cultivation, sampled household consumption patterns, details about Government schemes related to agriculture, farmers perceptions about climate change issues since last one decade and family health status features from blocks 15 through 20 (Sample questionnaire enclosed under Annexure 1.1) It may be noted that in the sample, the area of cultivation refers to the single largest cultivated area if the respondent owns more than one plot. Tenant farming ignored due to negligible presence of tenancy in field study area.

2.3. Demography of the Surveyed Villages

Table 2.2 describes the demographic characteristics of the surveyed villages. The average total geographic area (TGA) of surveyed villages is 1837 acres and the average number of households is 410. Further, the data reveals that average forest cover is 690 acres and net area sown is1357 acres across villages. The average population is 1661 across villages in surveyed villages. The percentage of Schedule Caste and Schedule Tribe population to total population is 30% and 16% respectively. An average of five small to medium range tanks (*i.e., Kuntalu* and *Cheruvus*) are there and around 20 borewells exist across villages. The data reveals that livestock is one main source of livelihood across surveyed villages and the average number of large and small ruminants is 230 and 509 respectively.

Table 2.2: Demographic Characteristics of the Surveyed Villages

Particulars	HHN	Population	SC	ST	TGA	Forest	Net Area Sown	Tanks	Borewells	Large Ruminants	Small Ruminants	SHGs	Rythu Mitra
Parvathapur	115	523	140	65	1400	NA	1400	4	30	30	122	8	NA
Jamgar Thanda	100	443	NA	343	236	NA	236	3	30	155	180	4	NA
Upparapalli Thanda	70	349	NA	349	210	NA	210	1	36	100	140	5	NA
Potpalli	600	2350	550	NA	2636	800	2336	12	10	350	300	40	NA
Motalkunta	650	2538	405	NA	NA	NA	NA	6	15	630	850	42	NA
Kalbemal	628	2300	300	NA	2750	180	NA	10	8	250	3500	38	NA
Chilkapally	290	1305	405	NA	2084		1884	6	6	305	1000	24	NA
Bidakanne	420	2123	1016	34	3098	1298	1800	3	13	300	200	40	NA
Shamshallpur	380	780	110	NA	1850	950	900	6	8	230	180	10	1
Malgi	820	1850	320	NA	1820	700	1120	2	6	310	810	24	2
Gunjoti	385	1030	100	NA	1620	200	1420	1	6	340	290	18	2
Huselli	290	720	620	NA	1350	150	1200	2	NA	190	190	15	1
Tekur	360	860	96	NA	1930	530	1400	3	4	320	210	16	1
Gottigarpalli	423	1496	592	523	3200	1200	1800	3	NA	110	450	150	38
Jadimalkapur	524	2691	666	NA	2500		2500	6	NA	250	600	160	50
Bilalpur	945	5000	1868	37	3500	900	3200	15	NA	175	400	180	72
Madri	600	2000	400	NA	2000	NA	800	7	NA	155	200	10	30
Shaikapur Thanda	104	NA	NA	561	138	NA	138	2	NA	104	104	3	9
Jamugaibod Thanda	41	NA	NA	225	97	NA	97	2	NA	40	100	3	4
Gurjwada	456	1555	350	NA	2500		2000	10	NA	250	350	10	20
Shaikapur	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Source: based on secondary and primary data.

2.3.1. Descriptive Statistics of Farm Level Characteristics and Socio-Economic Variables

Table 2.1 presents a summary of statistics of sample villages relating to various farm-level, socio-economic and market access variables. The average area owned by respondents was 2.34 acres in study villages of which, the average area under cultivation is only 1.61 acres. The quality of land is rated as medium quality and dominated by rain-fed agricultural practices. *Regadi, Sudda Banka Regadi, Garapa, Erra Garapa*, and *Erra regadi* soils are the dominant soil type in the surveyed villages. Table 2.1 further reveals that a substantial number of farmers practice cultivation of a greater number of crops in their farms. The average age of respondent was 49 years and most of surveyed farmers were in the backward classes with low level of education. The Average number of working people in respondents' households is close to 3 with poor agricultural amenities in across villages.

Table 2.3: Summary Statistics and Description of the Variables Used in the Analysis

Variable	Definition of the Variable	Mean	Std. Dev.
Plot level characteristics			
Area of the plot	Total area ownd (in acres)	2.34	2.91
Area of the plot	Cultivated area (in acres)	1.61	1.57
Soil type	Soil category (1 =Regadi; 2=Sudda Banka Regadi; 3= Garapa; 4= Garapa;5=Erra Garapa; 6=Suddamannau; 7= Erraregadi; 8= Neeru ChichuPattedi)	4.65	1.52
Land quality	Plot level soil quality 1= Poor; 2= Good)	1.64	0.48
Irrigation	Irrigation status (1=Rainfed; 2=Irrigated)	1.07	0.26
Crop diversification	Crop diversification level (1=Low level; 2= Modern level; 3=High level	3.06	3.56
Socioeconomic variables			
Age	Age of the household (in years)	48.9	12.55
Sex	Gender of the household (1=male;0=female)	1.25	0.45
Caste	Social status (2=socially forward class; 1=socially backward classes)	1.02	0.15
Education	Years of education of household head (1=Illiterate; 2= Primary; 3=Intermediate; 4=Higher)	1.51	0.86
Working age group	Number of people in the family	3.08	1.27
Household amenities	Household amenities index (1= High; 0=Low)	0.86	0.06
Agri assets	Agriculture assets index (1= High; 0=Low)	0.04	0.14
Ownership	Land ownership (1 =Male; 2=Female)	1.35	0.48
Household income	Household income level (1=0-10000; 2=10001-100000; 3= 100001-2000000)	2.13	0.68

Variable	Definition of the Variable	Mean	Std. Dev.
Market access variables			
Distance	Distance to dwelling (in km)	1.72	1.13
Road	Road connectivity of the plot (1=yes; 2=no)	1.38	0.49
Distance to market	Distance to the market from the plot (in km)	14.60	7.02

Source: *Author's own calculations based on field study data.*

The average distance from dwelling to the plot was 1.72 kilometers' and at an average, the plots had poor road connectivity. The average distance to the market is nearly 15 kilometers.

2.3.2. Cropping Patterns Adopted by the Surveyed Households

Rainfed agriculture practice is the dominant agriculture system followed across surveyed villages. Farmers cultivate variety of crops on their fields including jowar, bajra, finger millet, pearl millet, foxtail millet, kodo millet, little millet, red gram, black gram, cowpea, horse gram, soyabean, chilli, maize, ginger, cotton, and turmeric across the villages. One can witness that the majority of study village farmers practice millet-based agriculture rather than conventional agricultural cropping practices. Moreover, the outcome of group discussions with stakeholders and household level data suggests that more than 80% farmers sow more than one crop on their small plots with a number of varieties. Farmers who practice conventional agriculture had sown mostly one or two crops on their plots across surveyed villages. As will be seen, Chapter 3 offers detailed discussion on agricultural practices and specifically, on how SSS-Sangham millet, non-SSS Sangham millet, non-Sangham millet and conventional farmers practice farming across study villages during *Kharif* 2020-2021 period.

2.4. Summary

The objective of this Chapter is to describe the study location, sample design, survey instrument and questions. The survey was conducted nearly 1100 households from 34 villages of 5 mandals in Sangareddy district, Telangana during Kharif 2020-2021 period. Moreover, the study also conducted various focused group discussions with the stakeholders to gain a better understand not only quantitatively, but also qualitatively about cropping systems in Telangana. The study covers four categories of farmers including SSS-DDS-Sangham farmers, sample of non-SSS Sangham farmers, non-Sangham millet farmers and non-Sangham and non-Millet farmers to get heterogeneity of data.

Chapter 3
Millet Based Agriculture Practices Vis-A Vis Conventional Agriculture Practices - Insights from Field Study

3.1. Introduction

Deccan Development Society (DDS) communities have moved from self-reliance to self-abundant communities. As a result, the DDS communities have moved away from hunger, into health sufficiency and independent farming. Against this background, DDS has taken up Swasamruddha Samudyala Sankalpam, an initiative to double the farmers' income in one agricultural season in rain fed lands by encouraging the use of a mix of modern and traditional ecological packages.

In this chapter an attempt is made to understand the profile of the farmers adopting SSS farming, non-DDS farmers growing millets, DDS farmers who have not used SSS inputs and farmers adopting conventional agriculture. Factors such as soil types and quality, soil conservation measures adopted, major cropping patterns, crop and varietal diversity, sources of seed and manure used, incidence of pests, consumption of uncultivated foods, livestock and borrowings, are some of the critical issues discussed in the latter part of this chapter. This analysis is expected to provide information about the representativeness of the sample villages and further, help in getting insight into the organic farming practices of the sample farmers as against the practices of conventional farmers who are adopting chemical agriculture.

3.2. Soil Type

The soil types obtained in the study area varied from deep black cotton soils to light sandy soils. The kind and depth of soil also influenced the soil fertility. Generally, it is seen that soils with greater depth will be more fertile than shallow soils. It is evident from Table 3.1 that most of the farmers cutting across all categories own lands which have red soils slightly mixed with gravel soils. Thirty nine percent of conventional farmers own land that has black cotton soil. Nearly 13 percent of SSS farms were having lands with black cotton soils with drainage problem which is likely to have impact on crop yields.

Seventy eight percent of SSS farmers had lands with shallow depth soil of up to 2 feet (see Table 3A.1). As per table 3A.2, 42 percent of SSS farms were having good quality soils followed by 27.94% with average quality soils. Major soil conservation works taken up across all categories of farmers were soil bunding followed by stone bunding (see Table 3A.3).

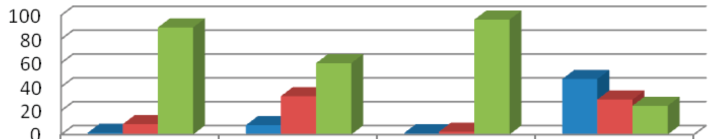
Table 3.1: Distribution of Sample households according to the soil types during Kharif 2020-21

Soil type	SSS farming (N=610)	Non-DDS-Millet farming (N=217)	DDS Non-SSS Farming (N=83)	Conventional farming (N=174)
Regadi (black cotton soil)	4.04	8.43	4.57	39.43
SuddaRegadi (Calcarian black cotton soils)	1.85	0.00	1.37	2.86
Banka Regadi (Black clay)	0.34	1.20	0.46	2.29
Garapa (Sandy)	12.29	1.20	10.96	7.43
YeeraGarbu (Red sandy)	68.52	84.34	74.89	46.86
SuddaMannu (Calcareous soil)	0.34	0.00	0.00	0.00
Erraregadi (Red clay)	0.00	4.82	7.76	1.14
Neeruchicchupattedi (Black cotton soil having drainage problem)	12.63	0.00	0.00	0.00
Total	**100.0**	**100.0**	**100.0**	**100.0**

Source: *Primary Survey*

3.3. Cropping System

Farmers of dry lands have developed diversified cropping systems to ensure that the most essential natural elements such as sunlight, wind, rainfall, and soil are optimally utilized throughout the year. Crops that were developed over centuries were specifically bred to suit the changes in rainfall pattern year after year. The short and long duration varieties, water tolerant and drought resistant varieties, etc., that were developed were the result of careful planning over centuries carried out by farming communities. Inter cropping, mixed cropping, relay cropping, and multi-tiered cropping were the strategies adopted by the sample farmers which were highly relevant to the rainfed geography.



	DDS-SSS farming	Non-DDS-Millet farming	DDS Non-SSS Farming	Conventional farming
Mono cropping	1.48	7.83	1.2	46.55
Inter Cropping	8.69	32.26	2.41	29.31
Mixed Cropping	89.84	59.91	96.39	24.14

Figure 3. 1: Percentage distribution of sample households according to their cropping system in the study area during Kharif 2020-21.

By doing so the farmers have balanced food and cash crops, along with the fodder needs of their animals and simultaneously managed the fertility of their marginal soils (Satheesh 2002; Pionetti & Reddy 2002; Reddy 2009a). Despite the constant encouragement for monocropping by the agricultural extension agencies and private seed, pesticide, and fertilizer companies for the past three decades, farmers still follow mixed cropping and inter cropping realizing its merit (Fig. 3.1). The adoption of this practice needs seeds of required quantities of diverse crops that are grown in the field. Just like crop rotation, this too has been a significant practice from the farmers' perspective in maintaining soil fertility management and managing crop pests.

Figure 3. 2: Major cropping system of the Zaheerabad region

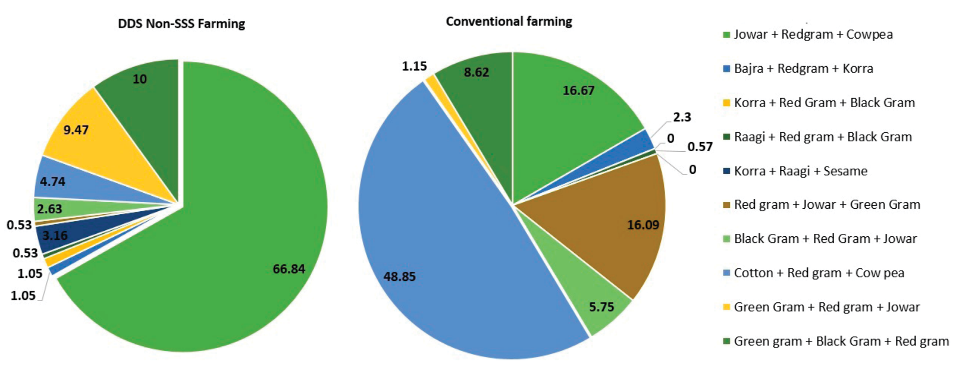
Among sample households of the study area, involved in SSS farming, during kharif 2020-21, mixed cropping was predominant (89.84 percent) and similar was the case with respect to non-DDS millet farmers and DDS non-SSS farmers. in contrast, in conventional farming, 46.55 percent of the farmers were adopting monocropping followed by 29.31 percent adopting intercropping and 24.14 percent taking up mixed cropping. Farmers value such diversity since it provides greater protection against the risk of crop failure (Scoones, 2001). The reasons given by farmers for the crop diversity include, access to diverse and nutritive food by the family members, availability of various kinds of fodder and feed to the livestock, improvement in the soil fertility, efficient utilization of farmland and the assurance that under no conditions of unfavorable environment and climate, the whole crop is lost.

Crop species diversity and intraspecific diversity are often identified as resulting in both nutrition security and ecological resilience (De Haan *et al.,* 2010; Lin, 2011; Jones, 2017; Reiss and Drinkwater, 2018). Figure 3.2 indicates that in the study area during 2020-21 there were different cropping patterns adopted by the sampled households (see box 3.1). Jowar +Redgram+ Cow pea was the dominant cropping pattern in the case of 76.80 percent of SSS farmers, 52.14 percent of Non-DDS millet farmers and 66.84 percent of DDS-non SSS farmers whereas in the case of 48.85 percent conventional farmers, Cotton + Redgram + Cow pea was the dominant cropping pattern. Even 13.57 percent of non-DDS millet farmers were adopting this cropping pattern. Redgram +Jowar + Greengram was another major cropping pattern adopted in the study region. Ragi + Redgram +Black gram was one of the important cropping patterns adopted by the non-DDS millet farmers. Because of the adoption of different cropping systems, there is approximately 75% drop in leaf biomass in the soil and fertility is enhanced. "*Barana raluthadhi chettumeedhi aaku. Rendu bandla aaku ralthadhi*" says, Moghulamma of potpally village. Each cart accommodates approximately 150Kgs of biomass. **"***Nalugu gampala aakuoka gampa yeruvuku samanam***", s**ays a woman (four baskets of leaf biomass is equally to one basket of farmyard manure).

Box 3.1: Major Cropping patterns in the study Villages

Village	***Agro-biodiversity: A common sight in dryland regions of Zaheerabad*** Farmers of dry lands have developed diversified cropping systems to ensure that the most essential natural elements such as sun, wind, rain, and soil are optimally utilized throughout the year. Crops that were developed over centuries were specifically bred to suit the changes in rainfall pattern from year to year. The short and long duration varieties, water tolerant and drought resistant varieties etc. that were developed were the result of careful planning over centuries by the farming communities. Intercropping, mixed cropping, relay cropping, multi-tiered cropping etc. were the strategies adopted which are always highly relevant. The following cropping pattern by three women from different parts of Telangana is a classic example of how the food and cash crops are balanced, along with meeting the fodder needs of the animals while simultaneously managing the fertility of their marginal soils. A minimum of 8-12 crops/varieties are seen in most of the small and marginal farmers' fields.
acchanaik Thanda	Jowar + Greengram/Black gram.; Til + Redgram (3:1) Korra + Redgram (4:1); Ragi + Redgram (3/4:1) Niger - Solo; Red Hibiscus + Bajra; Black Hibiscus + Jowar
Arjun Naik Thanda	Jowar + Redgram (3:1); Bajra + Redgram (3:1) Green gram + Redgram + one salPundi (3: 1 and one across line of Pundi). Blackgram+ Redgram + one salPundi (3:1 and one across line of Pundi). Korra + Redgram (3:1); Niger (Solo) and Kodo millet + Redgram (3:1)
JamgarBowli Thanda	Green gram + Redgram (3:1); Jowar + Redgram (3:1) Bajra/ Little millet/Korralu/ Yellow Jowar + Red gram + across lines of Field bean, cow pea (3: 1 + lines of Field bean, cow pea).
Potpally	Black gram (solo); Green gram + Redgram (3:1) Jowar + Redgram (3:1); Bajra/ Little millet/Korralu/ Yellow Jowar + Red gram + across lines of Field bean, cow pea (3: 1 + lines of Field bean, cow pea).
Rejinthal	Jowar + Redgram (3:1); Ragi + Redgram (3:1) and Korra + Redgram (3:1)

Source: Focus Group Discussions



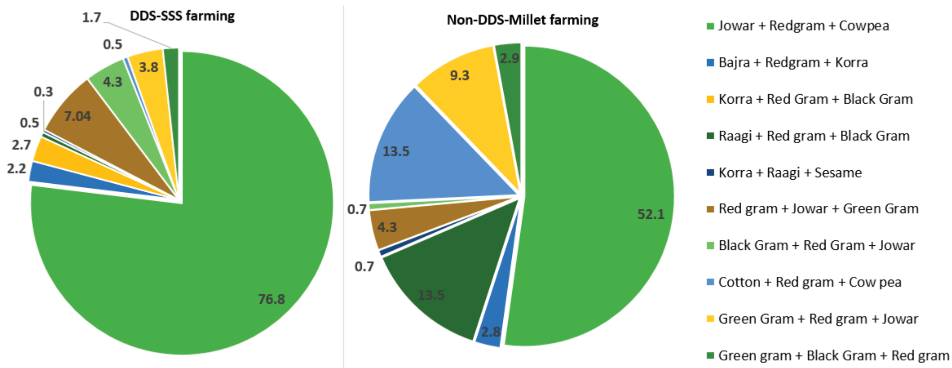
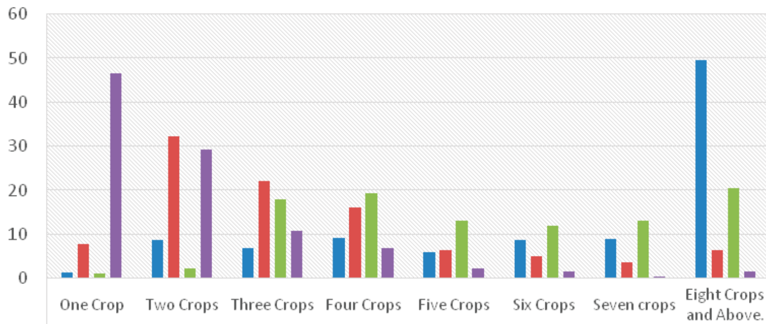


Figure 3. 3: Cropping pattern adopted by the sampled households during 2020-21(percent)

By practising inter/mixed cropping, farmers combine crops with varying root depth, thus avoiding competition for space, moisture, and nutrients. In mixed cropping systems, root diversity at different levels below the ground physically stabilises soil structure against erosion and soil movement on steep slopes, and in tropical systems, the contribution of roots to soil organic matter is proportionately larger than from above ground inputs. The effects of roots on soil biophysical properties are particularly critical in farming systems where crop residues are at a premium for fuel and fodder. Earthworms, other soil fauna and microorganisms, together with roots of plants and trees, ensure nutrient cycling; pests and diseases are kept in check by predators and disease control organisms, as well as by genetic resistances in crop plants themselves; and insect pollinators contribute to the cross-fertilisation of out crossing crop plants.

The natural process of biological nitrogen fixation by roots constitutes an important source of nitrogen for crop growth. It therefore provides a major alternative to the use of commercial nitrogen fertiliser in agriculture. Intercropping/mixed cropping will safeguard against total failure of the crops during unfavourable climatic conditions and has the potential to increase production and income on drylands (Singh 1979). Climate change will drive extreme weather events and the range expansion of infectious plant diseases and pests (Anderson *et al.,* 2004; Elad and Pertot, 2014; Bebber, 2015), which suggests that managing genetic diversity within crop species and keeping crop varietal diversity a part of the agricultural landscape can be an increasingly important focus to enhance food system resilience, i.e., the capacity to respond and recover from shocks (Frison *et al.,* 2011).



	One Crop	Two Crops	Three Crops	Four Crops	Five Crops	Six Crops	Seven crops	Eight Crops and Above.
DDS-SSS farming	1.48	8.69	6.89	9.34	6.07	8.85	9.02	49.67
Non-DDS-Millet farming	7.83	32.26	22.12	16.13	6.45	5.07	3.69	6.45
DDS Non-SSS Farming	1.2	2.41	18.07	19.28	13.25	12.05	13.25	20.48
Conventional farming	46.55	29.31	10.92	6.9	2.3	1.72	0.57	1.72

Figure 3. 4: Average number of crops grown by sampled Households during kharif 2020-21

Figure 3.4 shows that the crop diversity was more in the fields of DDS-SSS farmers as compared to conventional farmers. Nearly 50 percent of the sampled HHs adopting SSS farming have grown more than eight crops in each piece of 1 acre of land at a given point time, where in the case of conventional farmers the majority (46.55 percent) grew only one crop in their land at a given point in time. Nearly 46 percent of non-DDS millet farmers were growing a minimum of six crops in their fields. When it comes to DDS-non SSS farmers, the majority (32.26 percent) were growing only two crops followed by three crops (22.12 percent) in their lands at a given point of time. Conventional farmers are also cultivating diverse crops in their soils. However, 46.5 percent are growing only one crop, mainly cotton, 29.31 percent are growing two crops, and 10.92 percent are growing three crops. Notably, around 6.31 percent of conventional farmers are cultivating five or more crops in their soils. The reason cited by farmers for growing a variety of crops in the same piece of land is their ability to extract nutrition with different depths (*Vivida pantala verlu vivida lothunundi poshakalanu grahistai*). *Vivida pantala avasaralu veruveru ga untai* (Nutrient requirement of different crops is different so that there would not be specific nutrition deficiency). *Kulila avasaram veruveru ga untundi* (Labour distribution spreads across the year) *Chida pidala thakidi thakkuva* (Less incidence of pests & disease). Diversity provides some protection from adverse price changes in a single commodity and better seasonal distribution of inputs (Cacek and Langer, 1986). The benefits of crop diversity as expressed by farmers can be seen in Box 3.2

Figure 3. 5: Farmer displaying biodiversity in her farm

Varietal diversity of 7 and above was seen in 65.85 percent of SSS farmers' fields (see Table 3.2). Even, 48.15 percent of non-DDS millet farmers were having high varietal diversity of more than seven varieties. 86.78 percent of conventional farms had least varietal diversity followed by DDS- non-SSS farms (59.60 percent). Increasing reduction of crop variety is linked to the spatial displacement of traditional landraces.

Table 3.2: Varietal Diversity adopted by sample households according to their cropping system in the study area during Kharif 2020-21(per acre)

	DDS-SSS farming (N=610)	Non-DDS-Millet farming (N=217)	DDS Non-SSS Farming (N=83)	Conventional farming (N=174)
1-3 Varieties	16.91	11.11	59.60	86.78
4-6 Varieties	17.24	40.74	28.79	10.92
7 and above	65.85	48.15	11.62	2.30
Total	100.00	100.00	100.00	100.00

Source: *Primary Survey*

Increasing variety may lead to more sustainable food systems (Gatto, 2021). Farmers adopting SSS farming have wide varietal adoption in each crop which is clearly seen in table 3.3. Reduced levels of varietal diversity within and among fields result in increased vulnerability to biotic and abiotic stressors (Ceccarelli *et al.,* 2013), posing a threat to food security.

Table 3.3: Details of Varieties adopted by sample households in the study area during kharif 2020-21 by SSS farmers.

Crop	Variety Used	Variety Used	Variety Used	Variety used
Jowar (Sorghum bicolor)	Pajjonna (261)	Yerra Jonna (16)	Tellajonna (72)	Tellamallejonna (11)
Korra (SetariaItalica)	Tellakorra (3)	Yerrakorra (4)	Nalla Korra (1)	Manchu Korra (1)
Bajra (Pennisettumamericanum)	Desi sajja (2)	-	-	-
Red gram (Cajanus cajan)	YerraTogari (114)	Tellatogari (85)	Doddutogari (28)	Nalla Togari (3)
Green gram (Phaseoulus Mungo)	Ganga pesari (15)	BalenthaPesari (14)	Pacchapesari (11)	Teegapesari (1)
Black Gram (Vigna mungo)	Desi mnumu (7)	-	-	-

Source*: Primary Survey*
Note: Figures in the bracket indicate the actual number of households.

Box 3.2: Benefits of crop diversity as expressed by farmers

We get a range of nutritious food grains, dry and green fodder, fencing material, oil, ingredients for festival delicacies, food offerings, herbal remedies. It gives assured crop yield even during uncertain climatic conditions.

There will be reduction in pest and diseases due to population build-up of natural enemies. It acts as a cover crop and controls soil erosion. Conserves soil moisture. Maintains and enhances soil fertility. Sometimes equal quantities of janumulu (crotolariajuntea), pundi (hibiscus) and vulvalu (horse gram) which are part of mixed farming are crushed, grounded and fed to the animals; these are pounded together and used as animal feed by mixing small quantities of salt.

Not much workload on the family as different crops come for harvesting at different times. Creates employment potential to agricultural labour over different periods of time in a year. Gives different type of fodder for animals and the husk (pottu) of these pulses is very nutritious for the animals. There is a harvest of a range of uncultivated greens from the field in the cropping system as partner crops.

Source*: Focus Group Discussions*

Regarding the source of seeds used by farmers in terms of average quantity used per acre, Table 3.4 points out that for many crops SSS farmers were either using own seed, seed borrowed from farmers and seed supplied by DDS.

Table 3.4: Average seed quantity used in various crops by SSS farmers and conventional farmers (in Kg)

Crop Name	Own seed	Borrowed seed	Purchased seed	DDS supplied Seed
SSS Farmers (N=610)				
Traditional Jowar	4.18 (447)	3.61(53)	5.58 (17)	2.58 (83)
Hybrid Jowar	-	-	5.5 (2)	-
Traditional bajra	2.83 (9)	3.5 (5)	-	1.5 (2)
Hybrid Bajra	-	-	1.08(7)	-
Hibiscus	4 (2)	-	-	-
Green Gram	5.3 (32)	8 (4)	6.1 (5)	2.25 (2)
Black Gram	7.36 (11)	9.37 (8)	10.1 (6)	-
Red gram	5.28 (28)	7.8 (5)	7.125 (8)	10 (1)
Ground nut	-	-	3 (1)	-
Korra	0.77 (7)	2 (1)	-	1.33 (9)
Sama	1.6 (2)	-	-	2 (1)
Kodi sama	0.01 (1)	-	-	-
Ragi	0.75 (2)	-	-	4 (1)
Cowpea	-	-	-	3 (2)
Field bean	-	-	-	1 (1)
Sesame	0.65 (4)	1(5)	-	1 (1)
Conventional Agriculture farmers (N=174)				
Traditional Jowar	3.2 (9)	2 (1)	15.3 (3)	-
Traditional Bajra	5 (1)	-	-	-
Green Gram	3.8 (11)	10 (1)	12.8 (7)	-
Black Gram	5.75 (6)	5 (2)	5 (2)	-
Red gram	4.47 (18)	5.66 (3)	4.81 (11)	-
Foxtail millet	0.5 (2)	-	-	-
Finger millet	-	-	1.25 (1)	-
Sugarcane	1193 (13)	-	3094 (16)	-
Cotton	-	-	1.5 (37)	-
Onion	-	-	1 (1)	-
Soyabean	40 (1)	-	26.53 (25)	-
Ginger	400 (1)	-	400 (6)	-
Sesame	0.50 (1)	-	-	-

***Source**: Primary Survey*

Note: Figures in the bracket indicate the actual number of households.

SSS farmers are almost self-reliant with respect to the seeds and only a few households were buying seeds of a few crops from the market. On the other hand, conventional farmers were using their own seed and purchasing seeds of many crops from the market. These include commercial crops such as sugarcane, cotton, and soyabean. Similarly, details of seed use by non-DDS millet farmers and DDS non-SSS farmers can be seen in Table 3.4.

3.4. Usage of Manures

Sample households across various categories in general and SSS farmers in particular adopt different SFM (soil fertility management) practices in their fields. The practices adopted during the period kharif 2020-21 include Farmyard manure, Samruddhi yeruvu, neem cake, mycorrhiza, castor cake, tank silt, sheep penning and poultry manure (see Table 3.5). Sometimes farmers use more than one type of manure in a given field each year. Substantial quantities of farmyard manure are being used by all categories of farmers either from their own resources or by purchasing it from open market as can be seen from table 3.5. This is a crucial finding from the pest management angle. The higher the organic matter addition the better will be the resistance to pests and diseases. Conventional farmers who are cultivating crops such as ginger use copious amounts of farmyard manure and hence the average usage reflects more in their case.

Table 3.5: Crop-wise Average usage of Manures/Fertilizers in the study area during 2020-21(Kgs/per acre)

Type of manure	SSS farmers		Non-DDS Millet farmers		DDS Non-SSS farmers		Conventional agriculture farmers	
	Own	Purchased	Own	Purchased	Own	Purchased	Own	Purchased
Farmyard manure	3277	5113	3430	4971	5525	5603	3375	13600
Mycorrhiza	-	250gms	-	-	-	-	-	-
Vermiwash	25(ltrs)	3(ltrs)	-	-	-	-	-	-
Samrudhiyeruvu	15.0	0.0	-	-	-	-	-	-
Tank silt	-	-	500	8000	-	-	-	-
Sheep manure	-	-	-	-	-	80	-	300
Neem cake	10	3	-	-	-	-	-	-
Castor Cake	-	-	-	-	-	-	-	112
Vermicompost	-	-	-	-	-	-	-	25
Nadep/Aerobic Compost	-	-	-	-	-	250	-	200
Poultry Manure	-	-	-	-	-	-	-	2000

Source: *Primary Survey*

The practice of application of tank silt for improving the structure of soils is another key soil fertility management practice being adopted. Addition of tank silt not only improves crop yields but also improves the water holding capacity of light sandy soils.

Box 3.3: Fertility enhancing Inputs given under SSS farming

Under SSS the farmers were given training for Bio-3.5 pesticide preparation along with following inputs.

a. Samrudhiyeruvu: Samrudhiyeruvu is a combination of dry dung cake powder (3 baskets), vermicompost (3 baskets) and goat manure (4 baskets). Each farmer was given 10 Kgs /acre which is worth Rs150/-.

   (The majority of members used samrudhiyeruvu at the time of sowing. While few Of the farmers used it at the time of first weeding)

b. Vermiwash- (worms were given free of cost for establishing vermiwash units)

c. Panchagavya: cow urine (aavumuthram) (5 lits-free) cow dung (penda) (Kgs-free) Perugu (1 lits-50 Rs), Jaggary (1/2 Kg-50/-) and Ghee (1/2Kg Rs.600/-).

d. Mychorrhiza -1 packet.

***Source**: Focus Group Discussions*

3.5. Pest incidence scenario

Jowar, red gram, green gram, black gram, cotton, and soya bean were the major crops grown in the study villages. Analysis of pest incidence was done for all the major crops. Only those pests which caused economic damage were taken into consideration by farmers and the same was included for analysis. The occurrence of pests was seen to vary from year to year and the incidence was less during 2020-21. As per Table 3.6, SSS farmers are using non-chemical pest control measures whereas conventional farmers were using chemical pesticides. Major pests seen during kharif 2020-21 are traditional aphids, heliothids and pink bollworm.

Table 3.6: Pests and their control measures in the study area during kharif 2020-21

Pest control in SSS farms		
Pest Name	**Affected crop**	**Control measure adopted**
Aphids	Traditional jowar and green gram.	Spraying of cow urine followed by Ash sprinkling, and crop rotation
	Black gram	Spraying of cow urine followed by Ash sprinkling and spraying of jaggery water.
	Redgram	Spraying of cow urine followed by Ash sprinkling, and crop rotation
Heliothis (Pachapurugu)	Traditional Jowar	Spraying of jaggery water
	Redgram	Deep summer ploughing, varietal diversity adoption, sowing of trap crops, NSKE, cow dung + urine extract and crop rotation
Pest Control in conventional farms		
Aphids	Cotton	Fenverlate and chloropyriphos
Heliothis (Pachapurugu)	Cotton	Fenverlate and Trace
Pink bollworm	Cotton	Fenverlate, Endosulphan and crop rotation.

Source: *Primary Survey*

3.6. Livestock

This is a crucial factor influencing the soil fertility management practice of SSS and conventional farmers. Quantity and quality of livestock influences soil fertility management both directly and indirectly. The higher the livestock number, the more the access to organic manures. The livestock component of the farming system is crucial in maintaining soil fertility, supply of draft power and food for the family (Reddy 2009).

It can be seen from Table 3.7 that DDS-non SSS farmers of Deccan Development Society were having higher livestock. On the contrary, the conventional farmers owned a lesser number of animals across all categories. Livestock population has reduced due to the fodder and drinking water shortages resulting out of recurring droughts (Ranjitha, 2004). Especially, bovine population is coming down especially among large farmers. This could be attributed to reduction in farm size, increased mechanization, declining area under Common lands and changing patterns in labor availability (Conroy, et. al, 2001). Another reason is that children from SC and BC communities who used to earlier work for the landlords, are now going to school as a result of awareness created by voluntary organizations and the emphasis given by government on primary education.

"*Intlo magapillalu undi vyavasayam cheyalanu kune varu, yedlu unchukuntundru.*", said Moghulamma of Potpally village (respondent from one of the families where young men interested in farming are keeping the bullocks). In study villages, only 10-20 percent of the agricultural operations are carried out utilizing bullocks and the remaining work is done by tractor. Bullocks are exclusively used with Dinde and Danthe (these are agricultural implements used for inter cultivation. "Guntuku thoni pedithe dinde kottali, gorru thoti pedithe danthe pattali" (if you sow the crop with harrow you should opt for Dinde and if you use seed drill, you must go for danthe), said a farmer. The advantage of owning bullocks is that they need not pay hire charges for agricultural operations. Further, agricultural operations can be carried out in a timely manner and as result bullock owning farmers end up getting good crop yields.

Table 3.7: Per Capita Livestock owned by different categories of farmers in the study area during Kharif 2020-21

Category of Livestock	SSS farmers	Non-DDS-Millet farmers	DDS Non-SSS Farmers	Conventional farmers
Cows	0.55	0.13	1.19	0.17
Bullocks	0.11	0.07	0.24	0.06
Buffaloes	0.11	0.10	0.98	0.21
Sheep	0.001	0.0	0.0	0.0
Goat	0.95	0.61	2.22	0.27

Source: *Primary Survey*

3.7. Availability of Un-cultivated Foods (UCFs)

The assessment of prevalence of uncultivated foods presence in the farmers' fields reveals the existence of rich and diverse greens (see Table 3.8). Analysis revealed that pundi (hibiscus roselle) (62.11 percent) was the most consumed uncultivated food (see fig.3.5) followed by doggali (55.12 percent) and sannam doggali (28.94 percent). Rajgiri koora, jonna chenchali, gunugu korra and doddu payili are other major uncultivated foods consumed by the farming households. Women of Laccha Naik Thanda, during the FGD said that they consume Un Cultivated Foods at least 4-5 times a week. These include UCFs such as Pundi, doggali, bankatikoora, gungukoora, thotakoora, reliberi, bhaji, matir bhaji. With these UCFs we feel like eating an extra morsel of rice and they also give strength (*Bukkedu rottey ekkuva pothadhi*, *balam kooda vasthadi)*", says, Moti Bhai of Laccha Naik Thanda. Uncultivated foods like doggali are extremely popular with women. 'If it is available, we don't mind eating it even daily' (" *Dorakale kaani roju chesukoni thintamu*"), said a women farmer.

Box 3.4: Uncultivated crops – Major source of food

Rural people, especially the poor, consume uncultivated greens during various parts of the year as and when they are available. The poor people, who are mostly dependent on wage labour, harvest these crops and bring them home. Those who do not go to work in the village also gather with them from the nearby fields around the village. Greens like Pundi (Hibiscus Sp.) and Doggali koora (Amaratnth ussps). Greens like Chennangi (Lagerstoemia parviflora) and Soyi koora (Aurthum graveolus wild) are sold in the nearby towns as they are liked by everyone and have medicinal values. Greens like Talaili and Kashapandla chettu (Solanum nigrum) are never uprooted, as their availability is less and have high medicinal value. Even the landlords ask the agricultural labour not to weed these two plants, which shows its importance in the lives of people and their concerns to protect them. Uncultivated plant Kasapandla chettu is *called "Davakha naleni Mandu" meaning a medicine available without the existence of a hospital. Uncultivated plants are available throughout the year. Some are available in the rainy season and some in winter. Similarly, they are available in irrigated and drylands. Few greens are found in red soils and others in black soils. Rather than cultivating these wild plants, the women simply see that some of the seeds go into the compost pit, which will be then spread on the fields. And when they weed, they also take care to leave a few of these "unwanted grasses" to ensure their return in the following year. The use of chemical inputs has led to decrease in the availability of these leafy greens and hence the poorest sections of society are losing access to free sources of vitamins and minerals.*

Source: *Focus Group Discussions*

Consumption was more prevalent during the rainy season where the access to uncultivated flora is more. Some of them are available throughout the rainy season and others just for the first two months of the rainy season. These uncultivated foods are also specific to soil types and situations. Since these farmers always grow multiple crops at a time or engage in inter cropping, they get an assured variety of these uncultivated foods throughout the year which are harvested by women farmers at no cost and are largely used not only by them but also as green fodder for their cattle (see Box 3.4). The use of farmyard manure enhances the growth of these uncultivated foods in the field. Focus Group Discussions with women farmers revealed that these uncultivated foods were not prevalent in the farms of conventional farmers where the chemical fertilizers, herbicide and weedicides are used.

Figure 3. 6: Diversity of uncultivated foods in the DDS-SSS farmers' field

Table 3.8: Distribution of sample households according to the consumption of Major Uncultivated foods (UCF) in the study villages during the year 2020-21

Name of uncultivated food	Number of HHs consuming	Average quantity of UCF consumed Kgs	Average value of UCF consu-med by HH Rs.	Percentage of households consuming UCF
Pundi	382	9.36	207	62.11
Chiru Doggali	54	9.77	131	8.78
Doggali	339	8.53	184	55.12
Jonna chenchali	75	8.82	89	12.20
Kodi juttu	51	2.90	48.76	8.29
Teega Kodijuttu	36	3.3	18.36	5.85
Rajagiri kooora	114	7.13	179	18.54
Sannam Doggali	178	6.15	66.41	28.94
Doddu payili	104	5.34	88.72	16.91
BarreVayeli	27	2.44	30.77	4.39
Thota Koora	79	12.18	39.68	12.85
Gunugu Koora	104	13.13	222.18	16.91
Nallarjum	1	6	18	0.16
Tellarjum	7	7.85	194.28	1.14
Tagirancha	20	2.32	10.45	3.25
Adivi menthamKoora	1	0.5	2	0.16
Adivi Kakarakaya	13	4.23	161.76	2.11
Yelka Chevula koora	7	17	469	1.14
Munugaku	3	4	70	0.49
Gormeti Koora	42	14	87.30	6.83
Attheli Koora	1	1	4	0.16
Tellagarjala Koora	15	12.6	224.8	2.44
Yerragarjala Koora	7	2.14	9.42	1.14

Name of uncultivated food	Number of HHs consuming	Average quantity of UCF consumed Kgs	Average value of UCF consu-med by HH Rs.	Percentage of households consuming UCF
Tummi koora	47	2.57	26.55	7.64
Pappu Koora	3	17	59	0.49
Nalla kasha	1	4	5	0.16
Uttareni	3	5.66	59.66	0.49
Chennangi	1	1.5	3	0.16
Mentham koora	2	2.5	21	0.33
Chaya yeru	12	1.16	17	1.95
Paccha botla koora	1	12	36	0.16
Lambadi Koora	29	13.24	80.06	4.72
TellaBacchali	2	0.5	20	0.33
PullaKoora	1	4	16	0.16

Source*: Primary Survey*

Women believe that consumption of uncultivated foods keeps them healthy as they have high nutritional and medicinal properties. These UCFs have cultural significance too (Box 2.). They use these foods in different forms like curry and leaf extracts etc. to cure common ailments like headache, swellings, wounds, scabies, improper digestion, and major diseases like jaundice. Mogulama from Potipalli, said "Uncultivated foods create a society of equals by offering the best nutrition for the poor."

Box 3.5: Culture and Uncultivated Foods

Uncultivated foods were found to constitute an important part of farmer's culture. Different greens were mandatorily used during important festivals including those related to agriculture. The following table gives us an idea of some of the uncultivated food that was used during different festivals.

Uncultivated Food	Festival for which it is used
Tummikoora-	Vinayaka Chavithi
Pundi	Dusshera Pappu
Shaniga koora	Peerla Panduga
Mixed leaves of uncultivated greens	Shoonyam Panduga

Source: *Focus Group Discussions*

Fugure 3. 7 Pundi, the most consumed uncultivated food by the households in the study area.

3.8. Sources of Credit

Table 3.9 reveals that the majority (31.22 percent) of the SSS farmers of the study area depend on Deccan Development Society for loans. It was extending financial support of Rs.7500/- per member for millet cultivation in an acre of land. Some used this money for 1-3 acres. These were given towards expenses for ploughing, sowing, weeding and fertilizer."*Lekka pedithe avi saripovu sir, maa cheyi nunchi pettukuntamu*", said Sakhi bai of Laccha Niak Thanda (honestly speaking, this amount is not enough; we need to pump in our own money for cultivation).

On the other hand, it can be seen that majority of other categories of farmers did not get any loan from any institution. The empirical evidence clearly indicates that even today a considerable number of farmers borrow loans from money lenders. The formal credit agencies provide low-cost credit, facilities of repayment in installments and the possibility of postponement of repayment in case of crop failure (Mohanty and Shroff, 2004). Hence, the credit disbursement of these banks must be increased further to reduce dependence on private money lenders who charge exorbitant interest charges. Rural credit plays an important role in meeting the financial requirements of the resource poor (Adolph and Butterworth, 2002). Interestingly, the dependence on fertilizer and pesticide dealers is negligible in the study area.

Table 3.9: Distribution of Sample households according to their source of loan in the study area during 2020-21 (percentage)

Source of Loan	DDS-SSS farming (N=610)	Non-DDS-Millet farming (N=217)	DDS Non-SSS Farming (N=83)	Conventional farming (N=174)
Commercial Bank	28.13	7.14	23.50	29.55
Co-operative Bank	1.46	21.43	3.23	6.82
Money Lender	13.17	1.19	21.20	14.20
Input Dealer	0.33	0.00	1.84	0.57
DDS	31.22	0.00	5.99	0.00
Others	10.57	10.71	6.91	4.55
Did not get the loan	15.12	59.52	37.33	44.32
Total	**100.0**	**100.0**	**100.0**	**100.0**

***Source**: Primary Survey*

3.9. Sources of Agricultural information

Television was the most important source of information for SSS farmers regarding the weather. For information on quality seed, most farmers were dependent on peer group followed by DDS (Table 3A.7). For soil fertility enhancement, neighboring farmers were major source of information followed by DDS. While the main sources of information for diagnosis of pests and diseases, identification of natural enemies and marketing price of crop produce, were peer group, neighboring farmers, and DDS, for agricultural machinery the agricultural department was the main source of information. Even for conventional farmers, major sources of information on various aspects were mainly peer group and neighboring plot farmers. However, for diagnosis of pests and diseases, conventional farmers were depending more on local fertilizer and pesticide dealers.

3.10. Farmers' Perception on Climate Change

Given the recent climate change impact on agriculture, the present study tried to understand the farmer's perception regarding various impacts seen as a result of climate change. Farmers have given multiple responses with respect to these changes. Prolonged dry spells (60.98 percent) were the major climate change impact as per perceived by SSS farmers followed by elevated temperatures (57.38 percent) and erratic rainfall (56.39 percent). The majority (51.42) of conventional farmers reported hailstorms as major climate change impact followed by excess rainfall (37.71 percent) and elevated temperature (34.85 percent).

Table 3.10: Frequency of climate change incident in the last 10 years as reported by DDS-SSS farmers and Conventional farmers

Category	Drought	Erratic rainfall	Excess rainfall	Prolonged dry spells	Hot temperature	Heavy cold	Hailstorm
DDS-SSS farmers (N=610)	10.98	56.39	45.25	60.98	57.38	40.82	40.0
Convent-ional Farmers (N=217)	2.28	17.71	37.71	21.71	34.85	9.71	51.42

Source: *Primary Survey*

DDS-SSS Farmers have adopted different coping mechanisms to deal with the vagaries of nature. For delayed onset of monsoon, drought, and erratic rainfall, SSS farmers have delayed the sowing as coping mechanism (Table 3A.5) Soil and moisture conservation works have been major coping mechanisms for prolonged drought and high temperatures.

3.11. Conclusions

Bio-diverse based millet farming was predominant with majority of the SSS farmers, non-DDS millet farmers and non-SSS DDS farmers. Varietal diversity was high with SSS farmers. Their farming system took care of food and nutritional needs of the family, fodder needs of their livestock and fertility needs of their soils. Empirical data revealed that bovine population is dwindling, which is also influencing the access to Farmyard manure, crucial for the long-term health of the soil attributable largely to the lack of human resources to take care of them. Hence, there is need for a policy that ensures that all bullocks may be taken care by a herdsman for grazing as a herd and that MGNREGA funds be paid to these herdsmen as wages. This will be a win-win situation for both labor and agriculture. Millet farming could also withstand the vagaries of monsoon in a much better way as compared to other crops. *The study findings call for the need to strength the biodiverse based millet farming systems adopted by the women in the study villages through policy support.* This will help address the many farming challenges (crises) in the Telangana state, especially in the present situation of climate change.

Chapter 4
Economics of Millet Based Agriculture System

4.1. Introduction

In the preceding two chapters the study objectives and the design for collection of field data along with the village characteristics, and the differences between conventional and millet dominant agriculture prevalent in Sangareddy district of Talangana State were presented There has been a significant decline in the net sown area under millet-based agriculture across the country over decades contrasting with the increase in cultivated areas of other cereals due to various technological, input and output market policies (Dayakar, 2021).

Cultivated area under millets is largely distributed across the states Madhya Pradesh, Chhattisgarh, Tamil Nadu, Karnataka, Orissa, Maharashtra, Rajasthan, Uttar Pradesh, Andhra Pradesh, and Uttarakhand states in India. However, the data reveals that states such as Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Uttarakhand, and Rajasthan rank top in terms of crop yields among millet cultivated states in India. Despite millets having agronomic, climatic, and nutritional benefits, production has shown a significant negative   trend over decades in India. Input and market policies (especially, minimum support price) play a pivotal role in agricultural production. Post-Green Revolution, Government agricultural policies showed a bias towards staple crops inadvertently resulted in crowding out traditional millets (Pingili *et al.,* 2017). Indeed, as states like Karnataka and Tamil Nadu, the Government should include millets into Public Distribution System (PDS) at national level which serves to address the dual problem of food and nutrition security of the poor and improves income of the rainfed farmers. Further, ‘crop-neutral agriculture policies attract farmers to expand the net sown area of nutrition-rich crops in rainfed areas which would help mitigate the dual problem of food security and health (example, obesity) problems in India (Dayakar, 2021).

Available literature, while exploring extensively the cost of cultivation, net revenue, crop yields across cropping patterns neglected to account the total economic value of agricultural systems. Further, most of the studies accounted economic value of net revenue only[8] and neglected the other subsidiary revenues, for example production of cattle grass, biomass, and other subsidiary outcomes apart grain yields. Contrary to the notion that revenue from Millet based agriculture systems is less compared to other types of agriculture, the former requires less management costs while providing cumulative benefits to the farmer and enhances soil nutrients.

Deccan Development Studies have initiated five level inputs/methods in an innovative SSS package *to* improve soil fertility and pest management mechanism for improved crop yields. Recent literature on the impact of implants suggests that analysis based on Randomized Control Trials (RCT) is the most appropriate approach to overcome the selection bias via causal inference analysis, in which SWC measures are assigned randomly to a group of farmers while a control group of farmers cultivate without those specific interventions. Assessment of SSS benefits by RCT analyses is relatively rare due to practical difficulties in implementation. However, several studies adopted quasi-experimental approaches to analyse the causal inference in the context of agricultural outcomes (Faltermeier and Abdulai, 2009; Willy *et al.,* 2014; Singha, 2019). The present Chapter attempts to explore the total economic value of millet based agricultural systems compare to other cereal agricultural practices, specifically, the causal impact of SSS practices on agricultural outcomes. This Chapter also attempts to study the determinants of crop choice (especially, millet-based cropping system) in the study villages.

4.2. Methodological Framework

4.2.1. Analytical Framework

4.2.1.1. Binary probit model

The random utility model provides a basis for adoption of alternative crop choices. Both logit and probit models are well established methods to study farmers' decisions to adopt alternative crop choices. The choice of model is a matter of computational convenience (Green, 2018). The current study employs the probit model to analyze the adoption of alternative cropping systems. The probit model is defined by the following equation (Greene 2018; Bryan et al. 2009):

8 Here net revenue is defined as revenue from grain yields minus cost of cultivation.

$$y^{*}=\alpha + X\beta + u_{i} \ldots (4.1)$$

where y* denotes latent variable, explanatory variables (such as plot level characteristics, farmer socioeconomic characteristics and market access variables) defined by XX, $\beta\beta$ are those parameters need to be estimated, and error term is denoted by $u_i u_i$. In the probit model, the estimated parameters $\beta\beta$ do not provide direct interpretation. Therefore, it is necessary to estimate the marginal effects from the mean of each variable. The marginal effect for the $i^{th} i^{th}$ continuous variable is given by the following equation (Greene 2018):

$$\frac{\partial p(p=1)}{\partial x_j} = \varphi(\beta x) + \beta_j \ \ldots (4.2)$$

where φ is the cumulative normal density function. In the case of a binary variable, the marginal efects can be calculated by:

$$\Delta P = (y = 1) = \varphi\,(\beta_1) - \varphi\,(\beta_0) \ \ldots (4.3)$$

Thus, the marginal effect is calculated as the difference between the value with the dummy variable set at 1 and the dummy set at 0[9], holding all other variables at their mean values. This model is slightly more robust than the logit model.

4.2.1.2. Inverse Probability Weighted Regression Adjustment Model

As indicated, the randomized control trail approach is the best suitable method for causal inference analysis, in which SSS practices are already assigned randomly to a group of farmers while a control group of farmers do agriculture without those specific SSS interventions. However, randomized control trails are rarely implemented in practice in the context of organic farming measures. Hence, in the absence of randomization, the literature suggests a different quasi-experimental technique, which attempts “to create a situation where treatment is as good as randomly assigned” (Apel & Sweten, 2010). The present study adopts Rubin causal model to deal with missing counter factual problem (Roy, 1951; Rubin, 1974). The “fundamental problem of causal inference is that it is not possible to observe each individual having received the treatment and not having received the treatment from observational data, and only one of two potential outcomes is observed at any given time” (Holland, 1986). The main components of Rubin causal model (also known as Propensity Score Matching method, PSM) are individuals (i.e., farmers here), potential outcome and treatment affect. Here, adopters are specified as those who have gotten SSS interventions, while others are non- adopters.

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9 we have defined the dependent variable as 1 when the farmer adopts millet agricultural system and 0 otherwise.

In the case of binary framework treatment is specified as follows:

$$T_i = 1 \text{ if the farmer 'i' is an adopter of SSS measures}$$
$$T_i = 0 \text{ if the farmer 'i' is non adopter of SSS measures}$$

The treatment effect for adopter *i* can be written as:

$$T_i = Y_i(1) - Y_i(0) \text{ .... } (4.4)$$

The potential outcome is the differential between $Y_i(1) - Y_i(0)$. However, here we observe only potential outcome for adopter *i*. The counterfactual outcome comes from unobserved non-adopter *i.* The individual treatment effect is not possible here. The Average Treatment Effects (ATE) are the difference between expected farm outcomes between adopters and non-adopters.

$$ATE = E\,[(Y_i(1)|T_i = 1)] - E\,[(Y_i(0)|T_i = 0)] \text{ ...... } (4.5)$$

where Y_i is the outcome variable of farmer*, i.e.,* aggregate farm profit. Adoption of SSS measures and realization of outcome variables may be influenced by several explanatory variables (Heckman *et al.,* 1999; Caliendo & Kopeinig, 2008). Therefore, the estimated result based on equation (4.5) yields biased results. Ideally, outcomes on farms with SSS practices do not represent the outcomes on farms without SSS interventions due to the non-random and voluntary nature of practice (Caliendo & Kopeinig, 2008). The matching method is one feasible way of overcoming selection bias. The SSS practice decisions based on observables, once accounted for, makes it possible to construct for each SSS practices a comparable group of non-SSS practitioners who have similar characteristics. The matching technique is based on these underlying assumptions:

1. *Conditional independence assumption (CIA):* $Y_i(0), Y_i(1) \coprod (T_i \mid X)$ *or stable unit treatment value assumption (SUTVA)* (Caliendo & Kopeinig, 2008).
2. *Common support /overlap:* $0 < P\,(T_i = 1|\, X) < 1$ (Caliendo & Kopeinig, 2008).

The probability of SSS practice lies between 0 and 1 for both SSS adopters and non-SSS adopters. The common support assumption ensures that the farmer with the same observable covariates[10], can be both adopters and non-adopters with a positive probability. The implication of assumption 1 and 2 are that no unobservable factors influence adoption andfarm profit (Caliendo & Kopeinig, 2008). Another implication is that one farmer's adoption of SSS practice does not depend on another farmer's

10 Some of such covariates are the characteristics of plots, village level, farmer level socio-economic factors like age, land holding size, social category, gender.

practice. Once these assumptions are satisfied, the matching technique can be used to match adopters and non-adopters and create counterfactuals. The Average Treatment on Treated Approach (ATT) is written as:

$$ATT = E\,[(Y_i(1)|T_i = 1, X)] - E\,[(Y_i(0)|T_i = 1, X)] \quad \text{...... (4.6)}$$

However, since there are a large set of covariates, matching on covariates could be difficult and it can be resolved with the use of propensity scores (Hahn, 2010). The PSM estimator for ATT can be specified as follows:

$$ATT\,(PSM) = E\,[(Y_i(1)|T_i = 1, P\,(X)] - E\,[(Y_i(0)|T_i = 0, P\,(X)] \quad \text{...... (4.7)}$$

where, $P\,(X) = P\,(T_i = 1|X)$ is the propensity score, i.e., the conditional probability for a farmer to adopt SSS measures given his observed covariates '*X*.' Due to substantial number of observed covariates, the problem arises while matching. The literature refers to this as "the curse of dimensionality" (Caliendo & Kopeinig, 2008; Hahn, 2010). This can be resolved "if we can control scalar value function of observable covariates, namely, propensity score" which is generated from all covariates in vector X, to create counterfactual (Hahn, 2010). Here the propensity score is a function of plot level, socio-economic, village and community level characteristics. Therefore, ATT (PSM) is the mean difference of farm outcome between adopters and non-adopters.

So far, we have discussed binary adoption framework. However, as there are multiple agricultural practices and a farmer may choose more than one agricultural practice, the agricultural net revenue may depend on adopted agricultural practices. Hence, to address this issue (Imbens & Lechner, 2001), we have incorporated a multiple agricultural practices framework by generalizing three different and mutually exclusive categories of agricultural practices. By construction, each farmer chooses to participate in exactly one practice category form $[T = 1,2,3,4]$. The potential outcomes denoted by the vector $\{Y_1 Y_2 Y_3 Y_4\}$. For every group T, a realization of one outcome is possible. The remaining three outcomes are counterfactuals.

In the multiple adoption states, the ATT is defined as the pair-wise comparison between any adoption groups r ands, where r, s ϵ D and r ≠ sfor the participation

$$ATT_{rs} = E\,(Y\,(r)\,|T = r) - E\,(Y(s)|T = r) \quad \text{...... (4.8)}$$

The counterfactual means of SSS measure $E\,(Y(s)\mid T = r)$ cannot be observed. Here also, we impose assumptions like confoundedness and overlap of common support, as in the binary adoption case, we can identify ATT as follows:

$$ATT_{rs}\,(PSM) = E\,[(Y\,(\mathrm{r})\,|T = r, (Pr \mid rs\,(X)) - E\,[(Y(s)|T = \mathrm{s}\,(Pr \mid rs\,(X)) \quad ...... (4.9)$$

Where, $Pr|rs$ (X) is the conditional choice probability (Imbens, 2001). We make the following sets of comparisons in terms of impact on the three-outcome variables: 1) farmers who practice millet-based agriculture, but non- DDS SSS millet category compared to DDS-SSS; 2) farmers who practice millet-based agriculture, but non-DDS & Non-SSS Millet category compared to DDS-SSS Sangam farmers; 3) farmers who practice non-millet-based agriculture compared to DDS-SSS farmers.

4.2.2. Estimation Method

This Chapter utilized an Inverse-Probability-Weighted Regression Adjustment (IPWRA) method to analyze the causal impact of SSS measures on agricultural farm-level outcome. The IPWRA approach utilize weighted regression coefficients to estimate treatment effect, in which the "weights are the estimated inverse probabilities of treatment" (Wooldridge, 2010). The IPWRA approach involves three steps while estimating treatment effects. First, the probability of adopting SSS practice (i.e., the treatment model) is estimated using a simple multiple *logit* regression model. The predicted probabilities utilized in estimating the inverse-probability weights. The variables considered include plot level, household socio-economic, village level characteristics, and market variables. Second, the model used kernel matching technique to compare adopters and non-adopters (Caliendo & Kopeinig, 2008). Finally, the average outcomes for adopters and non-adopters are estimated, and the difference between these average outcomes provides the estimate of the treatment effects. The 'IPWRA' estimators combine models for the outcome and treatment status and 'IPWRA' estimators emerge naturally from a robust approach to missing-data methods. The 'IPWRA' estimators are also known as double-robust estimators (Wooldridge, 2007; Wooldridge, 2010). The results are estimated using '*t effects ipwra*' user written command in *Stata* (15.1 version).

4.3 Data and Descriptive Statistics

The data used in the study came from household and plot level surveys of around 1100 famers in five mandals of Sangareddy district in Telangana. The detailed discussion on data collection is presented in Chapter 2. This data is collected and analyzed only in kharif (*i.e., Vanakalam*) during 2021-2022 period. Table 4.1 shows the cost of cultivation across farmers. Average cost of cultivation is 10481, 8281, 11895 and 12843 INR/acre in DDS-SSS, DDS & Non-SSS, Non-DDS & Non-Millet and Non-DDS & Non-millet farmers respectively. However, labour, seed and fertilizer cost contribute more than 60% among surveyed farmers. Figure 4.2 shows that labor cost is higher compared to other input costs and contributes from 39% to 80% of total costs across surveyed farmers. Moreover, labor cost is significantly higher in millet-based agriculture (*i.e.,* DDS & Non-SSS Sangam, DDS & Non-SSS Sangam, and Non-DDS & Non-Sangam Millet) compared to non-millet based (*i.e.,* Non-DDS Sangam & Non-Millet) agricultural practices across survey villages. The discussion with farming communities (through qualitative survey tools) reveals that millet-based agriculture system requires more agriculture labor due to its diversified nature. A farmer from Potpalli village of Jarasamgam mandal in Sangareddy district said that "the distribution of human labor spreads across the season in their millet cultivated farms due to diversified agriculture system. The time of sowing, weeding, and harvesting of cultivated crops will not be the same days or weeks, hence, they must work across the season. Further, there is little scope for mechanization other than land preparation in this millet-based agriculture system".

Table 4.1: Summary of Input Cost Across Farmers (*in INR*)

Category	Statistics	Seed	Organic Input	Fertilizers	Pest	Labour	Total
DDS-SSS	Mean	1046	1639	200	21	7575	10481
	Std. Dev.	691	3219	1041	132	5642	6899
DDS & Non-SSS	Mean	767	851	58	0	6605	8281
	Std. Dev.	610	3525	527	0	3985	5254
Non-DDS	Mean	1434	535	844	44	9038	11895
	Std. Dev.	4252	2610	2035	154	6342	7879
Non-DDS & Non-Millet	Mean	5571	487	1285	471	5029	12843
	Std. Dev.	15634	2387	2054	914	6207	18310

***Source**: Author's own calculations based on field study data*

The seed cost contribution falls in the range from 9% to 43% of total input cost among surveyed villages. Seed cost is higher with 43% of total cost in conventional or non-millet-based agriculture practices among survey villages while around 10% of total cost in millet based agricultural systems. According to the farmers 'farmers who practice millet-based agriculture sow their own traditional seeds whereas farmers who cultivate non-millet crops they mostly procure from market sources and the hence the price of seeds is higher costs compared to own farm saved seeds.' Further, usage of organic inputs is significantly higher in millet-based agriculture compared to non-millet agriculture practices. On the other hand, fertilizers, and pest costs are higher in non-millet agriculture systems compared to millet-based agriculture systems. Based on field observations, non-millet crops tend to attract more pests compared to millet crops.

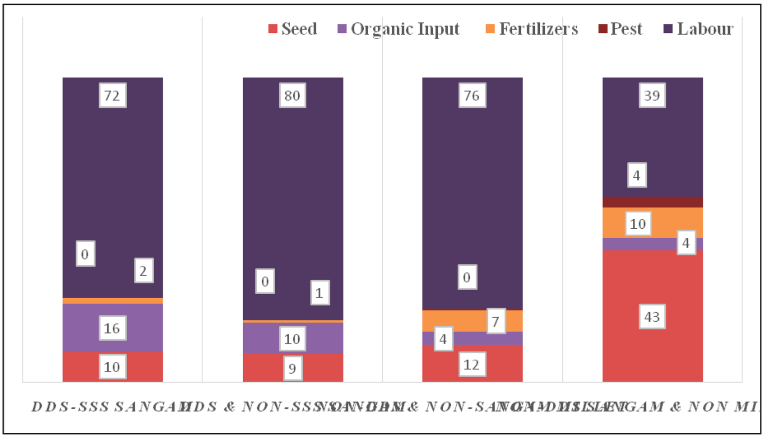

Figure 4.1: Summary of Input Cost Across Farmers (in Percentages)

Source: Author's own calculations based on field study surveyed data

Chapter 3 has offered detailed discussion on cropping pattern across categories in surveyed villages in the study area. Millet based agriculture system has mixed cropping and uncultivated foods and any valuation of returns needs to take into account all these. Table 4.2 shows category wise aggregate average agriculture returns. Unlike many other studies, the present study tries to capture possible aggregate of agricultural returns[11] rather than only crop returns value. The category-wise farmers of average aggregate returns from agriculture are 16786, 13626, 11250, and 25518 rupees per acre among DDS-SSS, DDS & Non-SSS, Non-DDS & Non-millet and Non-DDS & Non-Millet farmers respectively. Further, Table 4.2 shows that the aggregate value of non-millet based agricultural practices are significantly higher compared to millet-based aggregate agricultural returns. Further, average aggregate value of by-products, UCF and fodder are more compared to non-millet agriculture practices, whereas the mean value of grain yields is significantly higher in non-millet agricultural practices compare to millet-based agriculture systems. The extent of net sown area of any crop, production, and yields are primarily influenced by climate conditions, access to irrigation, infrastructure development *(i.e.,* road and market, integration with farms), and input and market policies (Joshi *et al.,* 2004).

11 Total agricultural returns is defined as aggregate value of grain yield, by-products (*i.e., Pottuporaka*), Uncultivated Foods (UCF), and fodder. We have estimated the by-products value per acre based on crop wise physical output and multiplied with corresponding monetary terms. The value of UCF per acre is calculated based on the value (*i.e.,* kg/acre) of uncultivated crops consumed by farmers and multiplied with market value of corresponding uncultivated food crops during Kharif 2021-2022 period; the fodder value per acre is estimated based on household survey data and outcome of conducted group discussions.

Table 4.2: Summary of Agricultural Output Across Farmers (*in INR/acre*)

Category	Statistics	Fodder	By-product	UCF	Grain yield	Aggregate returns	Profit	Profit (*expected*)[12]
DDS-SSS Sangam	Mean	822	171	743	15050	16786	6305	14045
	Std. Dev.	2564	331	1188	44250	48333	43374	39649
DDS & Non-SSS Sangam	Mean	223	569	1331	11503	13626	5344	13549
	Std. Dev.	608	2361	1615	10427	15011	13485	30124
Non-DDS & Non-Sangam millet	Mean	624	91	182	10353	11250	-645	8291
	Std. Dev.	830	205	264	11312	12611	12655	84182
Non-DDS Sangam & Non millet	Mean	199	93	154	25072	25518	12673	17579
	Std. Dev.	1033	173	349	45242	46797	46817	73999

Source: Author's own calculations based on field study data.

In surveyed villages, farmers are losing their farm returns significantly due to natural calamities (*i.e.,* heavy rains during harvesting, long spells of dry days during sowing and flowering time), pests, and birds and animal attacks. Table 4.2 shows that the loss of total value is 7740 rupees among DDS-SSS farmers and 8205, 8936 and 4906 among DDS & non-SSS, non-DDS & non millet and non-DDS & non millet farmers, respectively. Further, it also shows loss of aggregate returns at 55%, 61%, 108%, and 28% across DDS-SSS farmers, DDS & non-SSS, non-DDS & non-millet, and non-DDS & non millet farmers respectively.

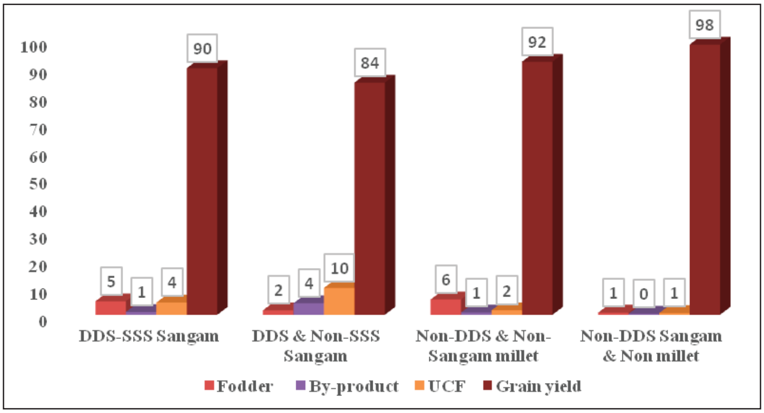

Figure 4.2: Summaries of Agricultural Output Across Farmers (in Percentages)

Source: Author's own calculations based on field study data.

12 This value is farmers' average expected aggregate returns across farmers in study villages if there is no loss due to natural calamities, pest, birds and animal attacks.

Figure 4.2 shows that the value of grain yields contributes more than 90% to total agricultural returns across surveyed farmers. However, the contributions from fodder, UCF and by-products are higher in millet-based agriculture compared to non-millet –based agricultural practices.

4.3.1. Explanatory Variables

As discussed in Chapter 2 the explanatory variables used to generate propensity score (i.e., propensity of agriculture practice) include, (a) plot-level characteristics such as area of the plot, soil type, land quality, irrigation, and crop diversification; b) socio-economic variables including details of the Head of the household, members of productive age in the household, household & agricultural amenities and household income; (c) connectivity variables including distance of the plot to the house, access to the road, and distance to the market from the plot.

4.3.2. Outcome Variables

Profit per acre during the monsoon season in 2020-2021 is considered as relevant outcome variable in the study area. Profit is estimated at aggregate level (i.e., overall cultivated crops) for each selected farmer. The aggregate level profit equals the revenue from all cultivated crops in the study area minus cost of cultivation of corresponding crops[13].

4.4. Econometric Model Results and Discussion

4.4.1. Logit model results

The binary probit model was estimated to identify factors that determine farmers' decisions to adopt alternative crop choices (i.e., millet-based agriculture systems and non-millet agricultural practices). Table 4.3 indicates that the overall explanation of the model reasonably good and significant ($Pseudo\ R^2\ is\ 0.34$ and $Prob > X^2$). The estimated model results suggest that out of the 17 variables that are hypothesized to determine crop choices, 10 variables are significant- soil type, soil depth, access to irrigation, soil erosion, agricultural implements, land ownership, experience of the household head, years of formal education of the household head, household income, and plot distance to market.

13 Cost of cultivation is estimated at aggregate level. The cost of cultivation includes cost of land preparation, seed cost, soil fertility input cost, chemical fertilizers cost, pest management cost, weeding and harvesting costs. However, these costs are collected crop-wise wherever possible. Otherwise, collected farm wise where there no provision for crop wise data available, for instance land preparation.

Table 4.3: Factors Influencing Choice of Millet Agricultural Systems: Estimates Based on Probit Regression

Explanatory variables	Model		Marginal effects	
	Co-ef	P>|z|	Co-ef	P>|z|
Choice of millet farming				
Plot-level characteristics				
Total area owned	-0.020	0.76	-0.004	0.75
Soil type (Garapa)	-0.420	0.66	-0.124	0.66
Soil type (Erra Garapa)	0.896***	0.00	0.237***	0.01
Land quality	0.138	0.60	0.030	0.60
Soil depth	-0.387*	0.10	-0.087	0.12
Irrigation	-0.769***	0.01	-0.197**	0.02
Soil erosion	0.568*	0.06	0.112**	0.03
Agricultural amenities index	1.694**	0.02	0.364**	0.02
Socioeconomic variables				
Ownership (Female)	0.500**	0.04	0.107**	0.04
Experience of the household head	-0.241***	0.01	-0.052***	0.01
Years of formal education of the household head (Primary)	-0.954***	0.01	-0.232***	0.01
Years of formal education of the household head (Intermediate)	0.103	0.76	0.020	0.75
Years of formal education of the household head (Higher)	-0.152	0.82	-0.032	0.82
Household income	-0.479***	0.00	-0.103***	0.00
Market access variables				
Road connectivity to the plot	-0.183	0.48	-0.039	0.48
Plot distance to dwelling	0.055	0.59	0.012	0.59
Plot distance to market	0.069***	0.01	0.015***	0.01
Diagnostic				
Observations				232
Wald chi2(17)				82.77
Prob > chi2				0.00
Pseudo R2				0.348

***, **, * indicate significance at the 1%, 5%, and 10% probability level, respectively.

Table 4.3 suggests that if farmers own red sand loamy soils, then they are more likely to adopt millet-based agriculture by 23% while controlling other constant variables. Farmers are more likely to cultivate millets if they perceive soil erosion. If the farmer has access to irrigation, then it is less likely to adopt millets by 11%. These estimated parameters suggest that millet based agricultural practices are more suitable to soils with less fertile and low irrigation conditions. Farmers are more likely to sow millets if they own more agricultural implements. If female owns the land title, then farmers are more likely to cultivate millets by 10%. Agricultural experience of the household head, access to formal primary education and household income negatively influence cultivating millets in the study villages. The results suggest that farmers with education and experience tend to choose conventional agricultural due to its market and minimum support price advantages. Further, if the farmer's plot is more than 1 km from the market, they are more likely to cultivate millets by 1%. This indicates that farmers close to markets and towns tend to cultivate conventional crops and farmers (i.e., marginal, and tribal communities) away from market are prone to choosing millets.

4.4.2. Inverse Probability Weighted Regression Adjustment Model

As mentioned above, IPWRA method is used to analyze the causal impact of SSS measures on agricultural aggregate outcome. The estimations are made using '*teffects ipwra*' user written command in *Stata*. The probability of adopting SSS practice (i.e., the treatment model) is estimated using *multinomial logit* regression model. The predicted probabilities are utilized in estimating the inverse-probability weights. Plot-level, socio-economic, and market access variables are used to estimate matching score.

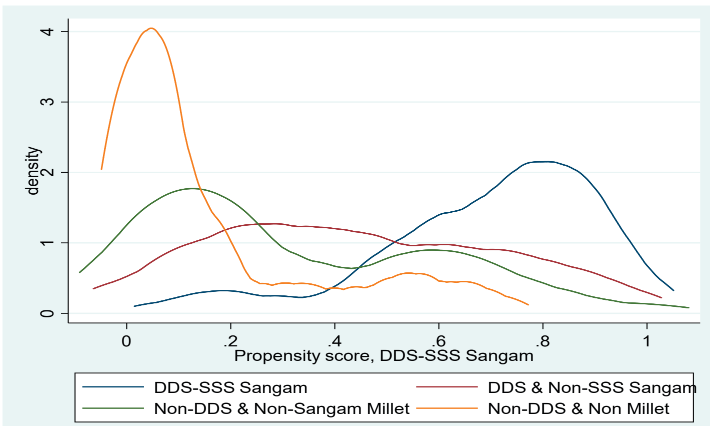

Figure 4.3: Kernel Density Distribution Showing Overlap between DDS- SSS, DDS & Non-DDS Millet and No-DDS & Non- Farmers

To check robustness of treatment effects on treated (ATT) models, the conditional independence and covariate balance are tested using '*tebalance summarize*' and '*teffects overlap*' user written commands in *Stata* and not violated. The results from *tebalancesummeraze* test are presented in Appendix 4.1. The results from 'teffects overlap' tests presented in figure 4.3 show the overlap in distribution of propensity scores and satisfy the common support condition.

Kernel matching approach is used while testing common support condition assumption. aCusal impact of SSS practices on aggregate profit has been estimated after ensuring matching of the covariates between adopters (*i.e.,* SSS practices) and other categories of farmers. The results suggest that there is a significant difference between SSS category of farmers and non-SSS category of farmers during study period in the study area. The findings show that the difference between DDS-SSS and DDS & Non-SSS in total aggregate profit attributable to SSS practices is about INR 4670 lower compared to DDS & Non-SSS farmers in the study area but not statistically significant. Further, findings also suggest that aggregate value of INR 4470, 5360 (at the 1% level of significant) is higher in DDS-SSS compared to DDS & Non-millet and Non-DDS &Non-millet farmers categories respectively in the study area (Table 4.4).

Table 4.4: Impacts of Adoption of SSS Measures on Agriculture Outcome

Outcome	ATT	P-value
In Terms of Rupees		
DDS-SSS (*Base value*)	8970***	0.00
DDS-SSS vs. DDS & Non-SSS	4670	0.40
DDS-SSS vs. DDS & Non-millet	-4470***	0.00
DDS-SSS vs. Non-DDS &non millet	-5360***	0.00

***, **, *Significant at 1%, 5%, and 10% probability level, respectively

Source: Author's own calculations based on field study data.

It is important, however, to note that the above may be overestimated due to attribution of benefits from SSS practices exclusively to soil fertility remediation. On the other hand, there may also be an underestimate by considering the implementation of conservation measures to result in improvement of provisioning services only, ignoring regulating, supporting and cultural services from the land ecosystem. The net effect of these biases on the model estimates necessitates further study and provides scope for future research.

4.5. Summary

This study estimated the impact of the SSS adoption measures using a survey of farmers in five mandals of Sangareddy district in Telangana. To estimate the causal impact of the adoption of SSS practices, a counterfactual comparison group using matching technique was created, assuming that it is possible to capture the factors that influence the farmers' decision to adopt SSS practices in their farms. Following this, propensity score was generated using a *multinomial logit* model to balance the observed covariates. The underlying assumption is that it is possible to capture the factors which influence the farmers' decisions to different category practices on their own. Matching of four groups was carried out using IPWRA method. The estimated results suggest that the farmers' aggregate profit increased in SSS practices compared to other category of farmers except non-SSS and DDS farmers. Further, these estimated models show higher bound result. Future course of work may consider understanding deeply.

Chapter 5
Summary and Policy Conclusions

5.1. Introduction

Agriculture plays a pivotal role in the economy of the state as elsewhere in the country. The better performance of the agriculture sector is vital for inclusive growth. More so dry land agriculture plays a significant role in achieving inclusive growth. The State of Telangana has around 37 percent of the cultivated area under a rain fed system. Due to low average rainfall, it falls under dry land agriculture system which is bio-diverse compared to irrigated systems. Livestock is crucial for dryland farming. Historically dry land farmers practised mixed farming to hedge the vagaries of dry land eco system. Productivity assessment in dry land eco system encompasses system yield and not just crop yields. Farmers consider along with grain yield, by-product yields (fodder and, husk yield) and contribution of biomass and farmyard manure to soil fertility. Eco-system services of dry land agriculture system are valuable and need to be netted in while assessing the economics of dry land agriculture system.

The DDS has enabled women Sanghams to continue the cultivation of traditional crops of jowar, millets and other crops native to the rain fed geography in Zaheerabad region of Sangareddy district. The dependence on markets for crop inputs is almost zero, the output is used for home consumption after which the surplus is marketed. The multifarious activities of the DDS in the realms of food sovereignty, food security, food processing, media and primary education handled by women, empowered them to become not only self-reliant but also achieve self- abundance. Women Sanghams conserve germ plasm of crops resilient to drought and/or prolonged dry spell situations making them self-sufficient. When the entire country and more so Telangana region faced an agrarian crisis and witnessed suicides of farmers during the past two decades, farmers of the dryland eco system like Zaheerabad have shown the way towards food security and well-being. Even during the recent Covid pandemic, DDS farmers have distributed food grains to many migrants. This goes on to demonstrate the resilience of crops the farmers cultivate. Moreover, these crops contribute immensely to better nutrition and health.

To enhance the productivity of the millet crop cultivated by the women sanghams, the DDS has rolled out the Swasamruddi Samudayala Sankalpam (SSS) farming, in one agricultural season (kharif of 2020-21) in rainfed lands, by encouraging the use of a mix of modern and traditional ecological packages (consisting of farm yard manure, Mycorrhizha, Panchagavya, Vermiwash and Beejamrutham) an initiative aimed at doubling the farmers' income. It is in this context that the present study has been taken up to understand and assess the economics of the 'Millet based Agro-Biodiversity Systems enriched with a mix of modern and traditional ecological packages in Zaheerabad region of Sangareddy District in the Telangana State'. The study compares the returns in terms of millet-based agriculture systems with and without SSS within the ambit of DDS and millet farming outside the purview of DDS and also the mainstream cultivation.

5.1.1. Methodology and Data Sampling

Zaheerabad area is predominantly rain fed with jowar, bajra, millets, pulses, maize, chilli, turmeric and cotton being the main crops in Kharif (*Vanakalam*) season. Purposive sampling method was followed to select the study mandals and villages, to understand the wide variations across villages in terms of crops and socio-economic heterogeneity. The study was carried out in 34 villages from five mandals of Zaheerabad region. Data was collected through a household survey covering 1094 farmers, categorized into four groups viz., DDS-SSS millet farmers[14], DDS-non-SSS millet farmers, non-DDS millet farmers, non-DDS and non-millet farmers.

The survey was conducted during the period from July 2020 to March 2021. The DDS has provided SSS intervention to around 600 farmers across villages to improve crop yields. All SSS DDS-Sangham farmers were covered, constituting a sample of 84 non-SSS Sangham farmers, 217 non-DDS Millet farmers and 176 non-DDS and non-millet farmers across 34 villages to capture heterogeneity. In each village, the list of households has been compiled from agricultural department data sets and simple random sampling approach has been adopted to identify the households for survey from complete list of households in the village. Moreover, Several Focus Group Discussions (FGDs) were conducted with various categories of sample farmers in some of the study villages, to capture the issues in detail.

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14 SSS is defined as *Swasamruddha Samudayala Sankalpam Farmers*, which consist of five farm-level inputs/methods including *Mycorrhiza, Panchgavya, Bheejamrutham, Vermivash and Samrudhi Yeruvu* to improve soil fertility and pest management mechanism.

5.1.2. Farm Level Characteristics and Socio-Economic Variables

The average area owned by respondents was 2.34 acres in study villages while average area brought under cultivation was only 1.61 acres. The land has medium quality soil and is dominated with rainfed agricultural practices. *Regadi, Sudda Banka Regadi, Garapa, Erra Garapa*, and *Erraregadi* soils are predominantly found in the surveyed villages. While mainstream farmers cultivated largely in black cotton soil, millet farmers cultivated mostly in red soil. Soil conservation work is taken up by farmers by way of soil and stone bunding. Black soils have drainage problems impacting crop productivity. MGNREGS funds need to be utilized on a continuous basis for soil conservation in dry lands, but quality of works must be ensured to reap the benefits.

Large numbers of farmers cultivating millets grow a higher number of crops in their farms. Crop diversity and variety contributed to soil conservation besides resilience to climatic vagaries, while this was absent among the farmers cultivating one or two mainstream crops resulting in mono-cropping. The average distance from dwelling to the plot was 1.72 kilometers and, on average, the plots had poor road connectivity. The average distance to the market is nearly 15 kilometers.

5.1.3. Cropping Patterns Adopted by the Surveyed Households

Farmers cultivate a variety of crops including jowar, bajra, finger millet, pearl millet, foxtail millet, kodo millet, little millet, red gram, black gram, cowpea, horse gram, soyabean, chili, maize, ginger, cotton, and turmeric across the villages. Most farmers from the study villages practiced millet-based agriculture rather than mainstream cultivation. Jowar, red gram and cow pea was the crop pattern followed by most of the SSS, non- SSS as well as non-DDS farmers. The combination of a millet crop, pulse crop and hibiscus are popular among millet farmers. Around 50 percent of SSS millet farmers have cultivated more than eight crops on one acre plot at any given time, whereas farmers who practice mainstream agriculture have sown mostly one or two crops in their plots across surveyed villages. Such mixed farming has been beneficial in many ways addressing soil health, fodder needs, food security, market price fluctuations for crops and labor requirement. A varietal diversity of seven and above is found among the SSS millet farmers while mainstream farmers had the least variety.

5.1.4. Traditional Ecological packages vis-a-vis conventional Farming: Insights from field

Bio-diverse based millet farming was predominant with majority of the DDS SSS millet farmers, DDS- non SSS millet farmers and non- DDS millet farmers. Varietal diversity was high with SSS farmers. Their farming system takes care of food and nutritional needs of the family, fodder needs of their livestock and fertility needs of their soils. Empirical data revealed that bovine population is dwindling over time, influencing the access to farmyard manure which is crucial for the long-term health of soil. With the average working people per household falling (the average per household number of working people is close to 3) and with children attending schools, maintaining livestock at household level has become a difficult proposition. A way out is a common herdsman who could herd the cattle for grazing and maintaining it either in a common place or at respective household level. This is like the traditional practice that was prevalent sometime back in the villages. MGNREGA funds may be utilized to pay wages to these herdsmen for the common upkeep of the village cattle. This will be a win-win situation for both laborers and farmers.

Pest infestation was commonly found for millet, pulse as well as cotton crops. Cotton crops faces risk of additional pests such as the pink bollworm. However, the pest control method varies across the millet farmers and mainstream farmers with its related cost implications as the latter are dependent on market purchased chemicals while the former use self- prepared bio pesticides.

One of the positive externalities which has positive nutritional effects for the household revealed in the study, is the uncultivated foods available in millet farming. These are available in abundance because pesticidal use is almost nil in such plots. During the crop season spanning 4-5 months, women collect such uncultivated foods 2-3 times a week on average. This ensures nutritional requirement for the entire household.

5.1.5. Economics of Millet based Agriculture Systems

This study attempted to estimate the causal impact of the adoption of SSS practices, by creating a counterfactual comparison group using matching technique, assuming that it is possible to capture the factors that influence the farmers' decision to adopt SSS practices in their farms. Following this, propensity score was generated using a *multinomial logit* model to balance the observed covariates. The underlying assumption was that it is possible to capture the factors which influence the farmers' decisions to follow the practices under various farming systems on their own by what is called the ATT (Annual Treatment on Treated) approach. The matching of four groups was carried out using IPWRA method. The per acre average cost of cultivation across the four categories of farmers shows it is highest in case of non-DDS non-millet or mainstream farmers and the least among DDS non-SSS farmers. The lowest cost for the latter category of farmers is due to non-application of SSS inputs[15]. The composition of costs shows that labor costs predominate among the millet cultivating farmers vis-s-vis mainstream farmers. The mixed cropping system followed by these farmers requires human labor which cannot be compensated for with machinery. A higher variation was seen in the seed cost with excessive costs for mainstream crop cultivation. Similarly, while organic fertilizer has a high share in mainstream category, the share of organic inputs is high among the SSS farmers.

The estimated results for per acre value of output for the four categories of farmers can be analyzed as millet farmers vs mainstream farmers and within millet farmers. The aggregate returns as well as the profits are higher for mainstream farmers compared to millet farmers. Within the category of millet farmers aggregate returns are higher for SSS farmers. Further, the result for these estimated models shows higher bound for expected profits. The share of value of fodder, by-product and UCF put together to total agriculture returns is around 10 percent for millet farmers but is almost nil in case of mainstream farmers. An estimation of costs and returns per acre of cultivated land for the four categories of farmers selected gives the results for aggregate returns, profits (aggregate returns minus total costs). The aggregate returns show that among the millet cultivating farmers the SSS farmers obtained highest returns at INR 16786. However, these are lower than the aggregate returns obtained by mainstream farmers and the difference in returns is INR 8732. The profits obtained by these categories of farmers show the same trend as aggregate returns, that is SSS farmers rank high among all millet cultivating farmers but have lower profits than mainstream farmers. Among the millet cultivating farmers non-DDS millet farmers obtained negative profits due to higher costs due to higher labor costs. It appears that non-DDS millet farmers have used more hired labor than family labor, while non SSS and SSS millet farmers have used lesser hired labor in that order.

The econometric model estimates the expected profit, which can be used to interpret the actual profit obtained as percentage of expected as well as the converse that is the loss percentage to expected value or profit. In the case of millet-based agriculture system the loss in crop yield is more as it is edible and considerable output is consumed by birds, pests and monkeys and wild boars attacking the crop. Besides long dry spell during sowing and flowering of the millet crop, heavy rain during harvesting have also resulted in reduced yield of millet crop. The latter events also affect all crops, even adjusting to common events the loss faced by SSS farmers due to events specific to

15 Though SSS inputs were given on subsidy basis to the SSS farmers by the DDS the value of these have been incorporated into the cost estimation

millet crops is at INR 7740 and for DDS non SSS it is 8205 and non-DDS millet farmers it is the highest at 8936. The least loss is faced by mainstream farmers at INR 4906. The difference between actual profit and expected profit is almost double that of the mainstream farmers. This has implication for policy to design interventions for human-animal conflict.

While the overall profit or loss is known it is important to know the impact of SSS interventions given by the DDS on productivity of millet crop. With appropriate matching of comparable sets of farmers by using the kernel matching approach the causal impact of SSS practices on profit has been estimated. The SSS farmers obtained a higher profit of INR 4670 compared to non SSS farmers, attributable to SSS practices but which is statistically not significant. In other words, it means the higher observable differences in profits between DDS – SSS millet farmers and DDS non SSS millet farmers are by chance. Further DDS SSS millet farmers could obtain INR 4470 compared to non-DDS millet farmers and DDS SSS farmers obtained INR 5360 compared to non-DDS non SSS farmers and these are statistically significant. In other words, DDS SSS farmers earned profits due to SSS practices compared to non-DDS millet farmers and mainstream farmers also.

5.2. Conclusion and Policy Recommendations

The overall findings of the study show that the millet-based agriculture system has advantages when an intervention like that of the SSS is made. The intervention has clearly made an advantage to the farmers practicing SSS in terms of profit compared to non SSS and non-DDS millet farmers. The attribution of benefit may be an overestimation of the practices of soil conservation due to the SSS interventions or also may be an under estimation by limiting to only conservation measures and not considering regulating and cultural services from the land eco system. The DDS women Sanghams have proved to be preservers of traditional millet-based crop system which have multi-dimensional benefits, and which needs to be handed over to future generations.

The present study found that millets are performing well in soils with marginal fertility in mixed farming systems, addressing food and fodder security, soil health, and emerging climate change issues. Though women Sanghams have played a key role in preserving these traditional cropping systems, non-DDS millet farmers also present a promising picture with respect to cultivating millets on their own. Hence, policy encouragement for millet cultivation will bring back more areas under millet farming, addressing pressing problems in rainfed areas of the country.

The policy recommendations flowing from the study are;

I. Millet production may be incentivized by making SSS packages accessible to farmers in dry land regions.

II. Women SHGs in the area may be entrusted with saving traditional millet germplasm in a big way and to make available the farmer saved seed to millet cultivating farmers.

III. MGNREGS funds may be utilized for common purpose activities like herding cattle of the farmers to increase the size of the livestock and the farmyard manure.

IV. It was found that all weather roads and access to markets, and extension services improve production as well as marketable surplus of millets. These need to be provided by the respective departments.

V. Encouraging millet-based agriculture system would generate several green jobs with employment potential for women.

VI. Markets for bio-fertilizers and bio-pesticides need to be developed to facilitate easy availability of these to the farmers intending to cultivate millets.

VII. Farmers' choice for millet cultivation is determined by individual factors such as gender and age. Women farmers in similar agro-ecological regions may be motivated to take up millet cultivation by the agriculture department.

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Appendix

A 3.1: Distribution of sampled households according to their soil depth during Kharif 2020-21

Soil Depth	SSS farming (N=610)	DDS Non-SSS Farming (N=83)	Non-DDS-Millet farming (N=217)	Conventional farming (N=174)
Upto 1 feet (very shallow)	29.41	46.91	64.52	15.43
1.1 to 2 feet (shallow)	47.55	43.21	25.35	30.29
2.1 to 3 feet (Medium)	20.26	3.70	7.83	22.29
3.1 to 4 feet	2.29	3.70	1.84	20.57
4.1 and above	0.49	2.47	0.46	11.43
Total	100.0	100.0	100.0	100.0

A 3.2: Distribution of Sampled Households According to their Soil Quality during Kharif 2020-21

Soil Quality	SSS farming (N=610)	DDS Non-SSS Farming (N=83)	Non-DDS-Millet farming (N=217)	Conventional farming (N=174)
Very Bad	16.01 (98)	21.95 (18)	34.56 (75)	21.71 (38)
Bad	12.91 (79)	13.41 (11)	17.05 (37)	21.71 (38)
Average	27.94 (171)	8.54 (7)	25.81 (56)	16.57 (29)
Good	42.32 (259)	50.00 (41)	21.20 (46)	37.71 (66)
Very Good	0.82 (5)	6.10 (5)	1.38 (3)	2.29 (4)
Total	100.0 (612)	100.0 (82)	100.0 (217)	100.0 (175)

A 3.3: Distribution of sampled households according their adoption of soil conservation measures

Soil Conservation measure	SSS farming (N=610)	DDS Non-SSS Farming (N=83)	Non-DDS-Millet farming (N=217)	Conventional farming (N=174)
Not done any thing	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Soil Bunding	72.58 (442)	79.01 (64)	79.26 (172)	81.61 (142)
Stone Bunding	21.84 (133)	12.35 (10)	17.51 (38)	13.79 (24)
Waste Weirs	2.46 (15)	7.41 (6)	2.76 (6)	3.45 (6)
Stone clearance	0.33 (2)	0.00 (0)	0.46 (1)	1.15 (2)
Bund planting.	0.49 (3)	0.00 (0)	0.00 (0)	0.00 (0)
Diversification Drains	1.97 (12)	1.23 (1)	0.00 (0)	0.00 (0)
Farm ponds	0.33 (2)	0.00 (0)	0.00 (0)	0.00 (0)
Rock Fill dams	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Other's	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Total	100.0 (609)	100.0 (81)	100.00 (217)	100.0 (174)

A 3.4: Average seed quantity used in various crops by non-DDS millet farmers and DDS-non SSS farmers

Crop Code	Quantity of own seed used	Borrowed seed quantity	Purchased seed quantity	Purchased from Government
Non-DDS Millet farmers				
Traditional Jowar	3.186(47)	6(6)	5(1)	-
Traditional Bajra	0.83(3)	-	-	-
Hybrid Bajra	5(1)	-	5 (1)	-
Hibiscus	0.91(3)	-	-	-
Green gram	2.25(10)	6.3(3)	-	-
Blackgram	-	-	-	6(1)
Redgram	6.6(6)	-	-	-
Korra	0.25(3)	-	-	-
Sama	0.5(1)	-	-	-
Finger millet	1(1)	-	-	-
Arikelu	25(1)	-	-	-
Cowpea	0.1(1)	-	-	-
Field bean	0.5(1)	-	-	-
Sugarcane	-	-	2(1)	-
Chillies	-	-	1(1)	-
Soyabean	-	-	25(1)	-
Ginger	300(1)	-	-	-
Sesame	0.75(2)	-	-	-
DDS-Non SSS farmers				
Traditional Jowar	4.7(111)	6.7(10)	6.5(6)	5.5(2)
Fodder Jowar	-	50(1)	-	-
Traditional Bajra	8(2)	-	-	4(2)
Hibiscus	10(1)	10(1)	-	-
Greengram	5.83(17)	-	2(1)	-
Black gram	-	10(1)	8(5)	-
Redgram	7(26)	10(5)	6.3(3)	-
Maize	2(1)	-	-	-
Korra	1.2(5)	-	-	1(1)
Ragi	-	1.5(2)	-	-
Feildbean	1	-	50(1)	-
Sugarcane	3750(2)	2000(1)	6333.3(3)	-
Cotton	-	1.8(9)	-	-
Soyabean	5(1)			
Sesame	0.5(1)			

A 3.5: Coping Mechanism adopted by DDS-SSS farmers to tackle the climatic changes.

	Delayed onset of monsoon	Drought	Erratic rainfall	Excess rainfall	Prolonged dryspells	high tempera--tures	Heavy cold	Hail storm
Did not take up sowing	36.55(68)	1.75(1)	5.10(15)	34.70(59)	0.0(0)	2.72(4)	20.0(1)	42.39 (39)
Delayed the sowing	52.68(98)	85.96(49)	41.15(121)	9.41(16)	0.0(0)	0.0(0)	0.0(0)	(11)
Sowing of alternate crop	0.53(1)	0.0(0)	0.68(2)	40.0(68)	2.27(4)	0.68(1)	20.0(1)	11.95 (36)
Adopted mixed cropping system	10.21(19)	0.0(0)	15.98(47)	12.35(21)	1.13(2)	0.68 (1)	20.0(1)	3.26 (3)
soil and moisture conservation work	0.0(0)	0.0(0)	13.26(39)	0.0(0)	71.02(125)	91.83(135)	20.0(1)	3.26 (1)
Taken up crop insurance	0.0(0)	0.0(0)	0.34(1)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	3.26 (1)
Use of drought resistant varieties	0.0(0)	0.0(0)	0.34(1)	1.76(3)	0.56(1)	0.68 (1)	0.0(0)	2.17 (2)
Use of farmyard manure	0.0(0)	12.28(7)	18.70(55)	0.58(1)	13.06(23)	0.68 (1)	0.0(0)	3.26 (3)
Supplemental irrigation	0.0(0)	0.0(0)	4.42(13)	0.0(0)	3.97(7)	0.0(0)	0.0(0)	0.0(0)
Use of Mycorhiza	0.0(0)	0.0(0)	0.0(0)	0.0(0)	5.68(10)	1.36(2)	20.0(1)	0.0(0)
Others	0.0(0)	0.0(0)	0.0(0)	1,17(2)	2.27(4)	1.36(2)	0.0(0)	0.0(0)
Total	100.0 (186)	100.0 (57)	100.0 (294)	100.0 (170)	100.0 (176)	100.0 (147)	100.0 (5)	100.0 (92)

A 3.6: Coping Mechanism adopted and its frequency (Conventional farming)

	Delayed onset of monsoon	Drought	Erratic rainfall	Excess rain-fall	Pro-longed dry spells	high tempera-tures	Heavy cold	Hail-storm
Did not take up sowing	4	0	0	0	0	0	1	1
Delayed the sowing	9	0	12	7	0	0	9	1
Sowing of alternate crop		0	4	8	0	0	0	0
Adopted mixed crop-ping system	13	0	2	4	0	0	0	0
soil and moisture con-servation works	0	0	0	0	7	11	0	0
Use of drought resistant varieties	0	0	0	0	0	0	0	15
Use of fard manure	0	2	2	0	5	0	0	0
supplemental irrigation	0	0	0	2	0	0	0	0

A 3.7: Details of source of information obtained by DDS-SSS farmers for crop production

	Mass Media				Networks				Extensions						
Particulars	Radio	TV	News paper	Magazines	Relatives	Friends	Peer farmer	Neighbouring plot farmer	Agriculture Deparment	DDS	Local fertilizers & pestcides	KVK	Agriculture University	Private companies	Anu-Other
Weather	1	213	19	4	76	98	203	146	5	208	1	31	1	1	2
Source of Quality seed	1	6	4	3	115	106	269	184	9	199	1	50	1	1	11
Soil fertility enhancement	1	6	8	1	33	75	158	200	5	197	3	131	1	1	1
Diagnosis of pest and disease symptoms	1	6	2	1	68	91	141	138	32	206	108	77	1	1	6
Knowledge of Natural enemies of pests					31	46	102	67	6	64	42	51	1		1
Knowledge of agriculture machinery		5	4	2	65	197	193	18	173	4	28	1	1	2	
Market price for crop produce		8	7	27	55	73	145	198	28	157		23	3	1	3

A 3.8: Details of source of information obtained by Non-DDS millet farmers for crop production

	Mass Media				Networks				Extensions						
Particulars	Radio	TV	News paper	Magazines	Relatives	Friends	Peer farmer	Neighbouring plot farmer	Agriculture Deparment	DDS	Local fertilizers & pestcides	KVK	Agriculture University	Private companies	Anu-Other
Weather	1	85	3	2	18	28	50	19	2	14	1	1	1	1	8
Source of Quality seed	1	2			25	32	83	27	1	11	1	1	1	1	8
Soil fertility enhancement	1			1	19	31	49	72	2	16	1	1	1	1	7
Diagnosis of pest and disease symptoms	1	1			22	31	51	41	5	13	39	1	1	1	8
Knowledge of Natural enemies of pests	1			1	20	27	45	37	2	11	35	1	1	1	9
Knowledge of agriculture machinery	1				22	34	76	71	3	11	1	1		1	9
Market price for crop produce	1	1		1	20	43	42	74	2	12	1	1	1	1	8

A 3.9: Details of source of information obtained by Conventional farmers for crop production

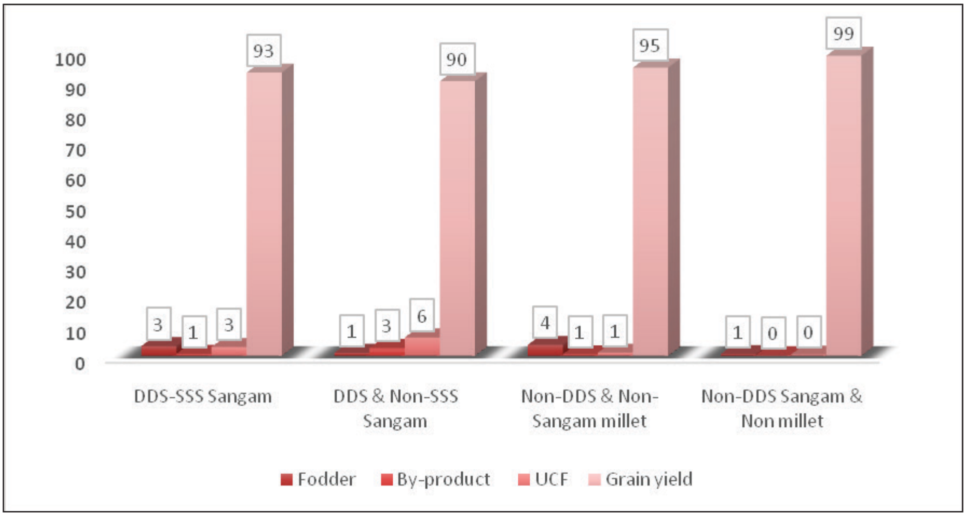
	Mass Media				Networks				Extensions						
Particulars	Radio	TV	News paper	Magazines	Relatives	Friends	Peer farmer	Neighbouring plot farmer	Agriculture Deparment	DDS	Local fertilizers & pestcides	KVK	Agriculture University	Private companies	Anu-Other
Weather	2	97	18	3	13	36	85	60	2	6	1	1	1	1	7
Source of Quality seed	1	11	4	2	22	45	98	74	7	10	9	1	1	1	7
Soil fertility enhancement	1	11	12	2	9	36	80	74		10	2	1	1	1	9
Diagnosis of pest and disease symptoms	1	10	6	7	12	31	69	67	6	8	31	5	1	1	7
Knowledge of Natural enemies of pests		1	3	2	16	25	56	53	2	3	1	3	1	1	6
Knowledge of agriculture machinery	1	10	12	2	17	34	84	71	1	2		1		1	6
Market price for crop produce	1	1		1	20	43	42	74	2	12	1	1	1	1	8

A 4.1: Over Identification Test for Covariate Balance

Variable Name	DDS & Non-SSS Sangam				Non-DDS & Non-Sangam millet				Non-DDS Sangam & Non-Millet			
	Standardized differences		Variance ratio		Standardized differences		Variance ratio		Standardized difference		Variance difference	
	Raw	*Weighted*	*Raw*	*Weighted*	*Raw*	*Weighted*	*Raw*	*Weighted*	*Raw*	*Weighted*	*Raw*	*Weighted*
Soil category	0.02	0.00	0.46	1.39	-0.40	-0.09	0.47	0.27	-0.79	-0.08	1.45	1.50
Land quality	-0.14	-0.04	1.67	1.12	-1.33	0.32	4.90	0.17	-1.17	-0.24	5.01	1.82
Soil erosion level	-0.54	0.00	0.19	0.99	-0.45	-0.21	0.31	0.11	-0.33	-0.21	0.50	0.12
Sex	0.20	-0.16	1.17	0.96	-0.17	0.57	0.84	0.75	0.27	-0.17	1.19	0.96
Education	-0.23	0.02	0.56	0.65	-0.44	0.26	0.54	0.34	-0.35	0.14	0.67	1.10
Working age group	0.33	0.11	0.64	0.68	0.29	0.38	1.27	0.80	0.38	0.54	1.25	1.03
Agricultural assets	0.18	0.20	1.57	1.50	0.16	-0.10	2.02	0.88	0.03	-0.13	1.32	0.56
Ownership	0.06	-0.12	1.08	0.91	-0.04	-0.27	0.97	0.77	0.49	-0.09	1.27	0.94
Household income	-0.91	-0.13	0.99	0.12	0.45	-0.69	1.04	0.34	-1.02	0.23	0.74	0.70
Access to road	0.05	0.16	1.02	1.01	0.16	-0.76	0.99	0.41	-0.21	-0.20	0.96	0.91

Source: Authors own estimations based on field level household data.

A 4.2: Summary of Agricultural Output Across Farmers (*in Percentages*)



Source: Author's own calculations based on field study data.

Note: Expected income if there are no extreme events

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