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India, Factor 6: Sustainable Agriculture

India does not have one national culture, but rather each region has its own language, traditions, and lifestyle. The nation's climate also varies, and the two major climates are tropical monsoon and temperate. Furthermore, when looking at a map of India, it is immediately evident that the terrain is vastly different in various parts of the country, including plains along the Ganges River, deserts, and the Himalayas (World Factbook, n.d.). Thus, in order to suggest a sustainable method of increasing food security in India, the nation cannot be studied as a whole. This paper will focus on two Indian states, Andhra Pradesh (abbreviated AP) and Telangana. Telangana became India's 29th state in 2014 when it separated from AP, and the two states' governments agreed to share Hyderabad as their capital city for ten years (BBC News, 2014). Most of the data and government programs described in this paper were collected or established before Telangana's split from AP.

The HH-01 Normal Households by Household Size data collected in the Indian census shows that the mean rural household size in AP and Telangana is 3.9 individuals, lower than the 4.9 average for rural India (Government of India Ministry of Home Affairs, 2011). Although the traditional family structure in the region is the joint family consisting of 8 to 10 people, nuclear families are becoming increasingly common (Kuhnlein and Pelto, 1997). Cheap cereals such as rice are integral to the diets of subsistence farmers in AP and Telangana, leading to an insufficient intake of vitamins and minerals and causing malnutrition (Shatrugna and Srivatsan, 2012). The Census of India's Andhra Pradesh Profile reports that the rural literacy rate in AP and Telangana for those aged 7 and older is 60.45%. However, there is great disparity between the literacy rates for males and females in rural AP and Telangana. Males have a literacy rate of 69.38%, and females have a literacy rate of 51.54% (Government of India Ministry of Home Affairs, 2011). Although a majority of the rural population of AP and Telangana is literate, they only have a primary school level education.

Health care is not readily accessible. Through the Aarogyasri Health Care Program established before Telangana's separation from AP, private and public hospitals based in Hyderabad set up camps twice a month in each district to "distribute medication, write referrals, and perform basic check-ups for the 1,000-odd villagers who attend . . . with the aim of educating rural families, many of them illiterate, about the availability of public health insurance," (Cox, 2013). However, serving 1,000 individuals at each camp is not nearly enough to satisfy the health care needs of 56 million people, the rural population of AP and Telangana in 2011 (Government of India Ministry of Home Affairs, 2011). Public hospitals in Hyderabad offer free medical care to all patients, but the hospitals lack proper equipment, drugs, and staff, and experience frequent power outages. Due to the decrepit conditions of public hospitals, rural farm families often choose to go to private hospitals for medical care, incurring great debt (Cox, 2013).

A majority of the population of AP and Telangana, 62%, is involved in agriculture (Government of India National Portal of India, n.d.). Almost 80% of farming households in AP and Telangana have fewer than 2 hectares of land, less than the national average family farm size of 5 hectares (Garcia, et al., n.d.; Qaim and Kouser, 2013). Known as the "Rice Bowl of India", rice is the states' main crop and staple food. AP and Telangana are also important chili pepper producers, as they together produce approximately 57% of the nation's chili pepper supply, equaling 21% of the world's chili pepper supply (Government of India Ministry of Agriculture (Department of Agriculture and Cooperation), 2009). Another important crop is coconut (Government of India National Portal of India, n.d.). To grow these crops, farmers, including subsistence farmers, in AP and Telangana practice "conventional, input-intensive farming that relies on periodic purchases of high-yielding seed, chemical pesticides, and chemical fertilizers," (Larson and Williams, 2012).

Located on the southern portion of the Deccan Plateau, the climate and soil quality in AP and Telangana are major barriers to increased agricultural productivity in the two states. Both AP and Telangana have infertile red loam or sandy loam soil and hot, largely arid to semi-arid climates (Baumann, 2008; Majumdar, 2015). The northeast portion of AP on the coast of the Bay of Bengal has a humid to sub-humid climate and clay loam soil (Prasada, Rao, and Rao, 2010; Singh, 2005; Hu, Yue, and Luck, 2001). The states are also highly dependent on the monsoons for rain. AP and Telangana receive a total of 923 mm of rain each year, with 67% of rainfall occurring during the south-west monsoon from June to September. Abnormal south-west monsoons are the main cause of drought in the region and devastate rural farmers. Drought occurs relatively frequently, as AP and Telangana experienced 20 droughts in the years 1970-2010 (Prasada, Rao, and Rao, 2010). Climate change would worsen the droughts and make them less predictable (Assman, 2013). A study conducted in Hyderabad found that increased temperatures due to climate change would lower the biomass of rice grown per hectare of land. There is high climate variability in AP and Telangana, and climate change would exacerbate this, especially in semi-arid and arid regions (Prasada, Rao, and Rao, 2010).

Salinity of the soil also poses a major problem for the subsistence farmers in arid and semi-arid areas of AP and Telangana. Arid and semi-arid soils have high concentrations of soluble salts that dissolve when the land is irrigated (Singh, 2005; Flowers, 2004). There is also no effective drainage of irrigated land, leading to a buildup of dissolved salts in the soil (Raju, 2001). Salinity lowers the amount of water available for plants, worsening the dry conditions in AP and Telangana (Abrol, Yadav, and Massoud, 1988). High salinity has little effect on the germination of rice, but it decreases the grain yield (Shrivastava and Kumar, 2015; Grattan et al., 2002; Flowers, 2004). For every 1dS/m increase in EC above 3.0 dS/m, the yield of rice decreases by 12% (Grattan et al., 2002). While high salinity of soil is less problematic for chili pepper growth, as the upper limit for the salinity of soil used for chili growth is 7.0 dS/m, salinity lower than 3.0 dS/m is ideal (Flynn et al., 2002). In general, salinity affects 50% of the world's irrigated land and the world is currently seeing a loss of arable land due to salinization (Assmann, 2013; Fedoroff et al., 2010). Soil salinity is less problematic in coastal AP. The clay loam soil in coastal AP is slightly saline and has an EC of 2.06 dS/m (Hu, Yue, and Luck, 2001; Natural Resources Conservation Service, n.d.).

Debt is another major issue for farmers in AP and Telangana. The agricultural practices in the two states require copious amounts of chemical pesticides and fertilizers, and these make up an approximate 35% of cultivation costs. This is 5 percentage points higher than the national average. Subsistence farmers in the region go into debt in order to purchase pesticides and fertilizers, and 82% of them are in debt. Not only is this the highest prevalence of debt among Indian farmers, but the average outstanding debt for a farmer in AP or Telangana is twice the national average (Larson and Williams, 2012).

The challenges of input-intensive farming in AP and Telangana have led to a push for more sustainable methods of agriculture. In the late 1990s, the government of AP created the Society for the Elimination of Rural Poverty (SERP). SERP organizes self-help groups (SHGs) of 10-15 individuals to work together for "collective saving, lending, and other activities that enable them to build an asset base." SHGs are usually groups of farmers or groups of women. Approximately 20 SHGs are united in one village organization (VO). VOs help SHGs find loans, organize community seed banks, and help villages plan their agriculture. About 300 VOs together make up a subdistrict federation. Some duties of the subdistrict federations include working with agencies in the state government, managing NGOs, and providing for microfinancing. A total of about 40 subdistrict federations make up a district federation. District federations oversee convergence with government programs, organize and maintain ties with the private sector, and control information systems. The goal of SERP is to promote community-managed sustainable

agriculture (CMSA). CMSA involves VOs educating farmers about the effects of chemical pesticides and fertilizers, organizing community seed banks and equipment centers, and helping farmers with finance. District federations use funding from the National Rural Employment Guarantee Scheme, an existing social safety net, to promote CMSA. While individual families have their own farms, farmers often work on each other's farms because decreased use of chemical pesticides requires more labor to protect crops from pests (Larson and Williams, 2012).

It is important to utilize SERP to improve the food security of subsistence farmers in AP and Telangana. SERP already promotes CMSA, and promoting community-managed sustainable hydroponics and controlled environment agriculture (CEA) would benefit farmers even more. Hydroponics involves growing plants in nutrient solution, using a solid substrate as an alternative for soil. CEA involves "control of air and root temperature, humidity, atmospheric gas composition, light, water, growing medium, and plant nutrition." As hydroponics does not require soil and uses less water than conventional agriculture, it is especially useful in AP and Telangana, where the soil is infertile and drought is common (Jensen and Malter, 1995). When used with CEA, hydroponics can eliminate the presence of pests, fungi, and bacteria harmful to crop growth, ending farmers' dependence on pesticides. Plants grown hydroponically also grow faster than plants grown conventionally, and produce a greater yield than plants grown using traditional methods (Shrestha and Dunn, n.d.). This would decrease the outstanding debts of farmers in AP and Telangana and even save lives, as many farmers commit suicide due to an inability to pay debts (Pokharel, 2015).

In coastal AP, hydroponics and CEA should be used to quicken the growth of rice seedlings, then the seedlings should be transplanted outdoors (Kim et al., 2005; "Starting Vegetable/Flower Seeds Indoors", n.d.). Hydroponically-grown rice seedlings with short growth cycles should be transplanted when they are comparable to 3 to 4-week-old, traditionally-grown seedlings. Hydroponically-grown rice seedlings with medium to long growth cycles should be transplanted when they are comparable to 4 to 5-week-old, traditionally-grown seedlings ("Information on rice [PDF document]", n.d.). This shortens the amount of time rice will be grown outdoors, and lessens the rice seedlings' exposure to pests and diseases ("Starting Vegetable/Flower Seeds Indoors", n.d.). Rice farmers in AP can thus alter their traditional rice-groundnut cropping pattern to add an extra harvest of a chosen crop ("Information on rice [PDF document]", n.d.). However, farmers should avoid planting rice if the weather becomes too hot for successful growth, as temperatures in AP can reach up to 50℃, significantly higher than 42℃, the maximum temperature rice can withstand (Majumdar, 2015; "Information on rice [PDF document]", n.d.). Furthermore, rice grows well in humid climates where there is a consistent water supply, so farmers in semi-arid and arid areas of AP and Telangana should avoid growing rice due to the frequent droughts in the area, and also avoid irrigating soil in order to prevent an increase in soil salinity ("Information on rice [PDF document]", n.d; Singh, 2005; Flowers, 2004).

Farmers can also grow chili peppers hydroponically, reducing the amount of water, chemical fertilizers, and chemical pesticides they require to grow the important crop. Chilies are frost-intolerant crops that require warm weather, ideally 21℃ to 27℃, and are more drought-tolerant than tomatoes and eggplants (Meagy, n.d.). While chili pepper growth is inhibited when the temperature rises above 30℃ for prolonged time periods, chili peppers are grown year-round (Government of India Ministry of Agriculture (Department of Agriculture and Cooperation), 2009). AP and Telangana both have hot climates, so chili peppers can grow there throughout the year, and farmers do not need a highly-controlled environment to grow them (Majumdar, 2015).

Hydroponics and CEA can be made ideal for AP and Telangana. Coconut husk fibers can be used to create a hydroponic substrate called coir (Choi et al., 2013). Farmers today use rice husk as fuel in furnaces, mulch for soil, feed for poultry, and packing material ("Information on rice [PDF document]", n.d.). However, while rice husk has not been widely used as a successful hydroponic substrate, its use

may be highly cost-effective in AP and Telangana (Kinoshita et al., n.d.). Rice husk's effectiveness as a hydroponic substrate should be tested with various different crops, including chili peppers. An important topic of research is if rice can be grown hydroponically using rice husk, as well as if rice can be grown hydroponically until ready to harvest, rather than growing only seedlings. Also, as hydroponics uses less land than conventional farming, farmers can use their land to grow a greater variety of nutritious crops to supplement their diets and prevent malnutrition. Hydroponics and CEA also require less labor than conventional agriculture because plant diseases are not major problems when growing food using hydroponics and CEA. This would allow children in farm families more time to attend school and increase the literacy rate in AP and Telangana.

The greatest barrier to growing food using hydroponics and CEA in AP and Telangana is the high initial cost involved. The major capital costs include building a greenhouse, creating irrigation systems to use for hydroponics, and obtaining the equipment necessary for heating and cooling the greenhouse. After that, the major costs include buying seeds, electricity, and nutrients ("Strawberry Production Costs in Greenhouse", 2015). SERP can help farmers overcome this obstacle and start growing crops hydroponically. District federations can continue to use funding from the National Rural Employment Guarantee Scheme and can use it to educate farmers about hydroponics and CEA. Subdistrict federations can work with NGOs to raise money to build greenhouses suitable for hydroponics. Each SHG would share a greenhouse in order to cut down capital costs, but individual farmers would be responsible for growing their own crops.

Another way to make hydroponics a practical option for subsistence farmers is to eliminate some of the major costs. The author of this paper traveled to Hyderabad during the summer of 2016 in order to study the productivity of a deep flow technique (DFT) hydroponic system that did not use electricity. She compared the growth of spinach and chili peppers in two identical DFT systems, one using an electrical air compressor to oxygenate the nutrient solution in the system, and one requiring manual oxygenation of the nutrient solution. Both DFT systems were located inside a greenhouse built using a shade net. The greenhouse provided a minimally-controlled environment that lacked heating and cooling systems; thus the manually-oxygenated DFT system did not require electricity. An analysis of the costs associated with each DFT system, including the costs of the seeds; materials; water; electricity used, if applicable; and labor required to build the systems and greenhouse will help determine if electricity-free hydroponics is viable in rural AP and Telangana. While in Hyderabad, the author also tested the success of rice husk as a hydroponic substrate by comparing crops grown using rice husk and crops grown using coir. The author details both social and scientific experiences in Hyderabad in her blog "Hydroponics: A Practical Option for India?" (http://practicalhydroponics.blogspot.com).

For SERP to successfully promote community-managed hydroponics, it must identify the obstacles SHGs for farmers would face during implementation of SERP's plans, help farmer SHGs secure funding for their hydroponic systems, and educate farmer SHGs in how to practice sustainable agriculture. SERP must also work with the SHGS for women, as subsistence farmer families must understand why the primary farmers should adopt community-managed hydroponic techniques in order to support the farmers. Without support and encouragement from the family, SERP's efforts to promote CMSA would be unlikely to succeed. In addition, micro finance in SHGs is known to empower women psychologically, socially, and economically by teaching them new skills and improving literacy through training sessions and income-generating activities (Sarumathi and Mohan, 2011). Women aged 20 to 30 years old experience the greatest benefits of micro finance in SHGs, which is especially important in India, the nation with the greatest population of young people in the world (Sarumathi and Mohan, 2011; "India has world's largest youth population: UN report", 2014). As the benefits of micro finance come through training sessions and income-generating activities, SERP-led SHGs can use similar techniques to empower the wives of subsistence farmers.

Using AP and Telangana as models, other Indian states can improve their sustainable agricultural practices and work towards greater food security. The Aarogyasri Health Care Program, a state-level program, uses funding from the federal government's existing Minimum Common Need Programme, commonly known as the "ration card program", to operate (Cox, 2013; Food, Civil Supplies and Consumer Protection Department, n.d.). Other Indian states can also use funding from the ration card program to establish state-level organizations, like SERP in AP and Telangana, which promote CMSA.

A state-by-state approach is the best way to improve India's food security due to the great diversity in the cultures, climates, and terrains of different states. The government of each state can assess the unique obstacles to sustainable agriculture in the state, then use AP and Telangana as examples for how to implement new programs or modify existing programs to remove or lessen the obstacles. In this way, both the improved agricultural techniques and the programs promoting them are sustainable, saving countless lives and improving even more.

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