

# ***Exploring Business Models for Water Efficient Agriculture in India***

Client: NatureVest, The Nature Conservancy



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## A. EXECUTIVE SUMMARY

With 17 percent of the world's population but only 4 percent of global freshwater resources, India is facing a water crisis. Currently, 90 percent of India's 1.5 billion people live in areas that are experiencing some form of water stress. By 2050, the Indian population is anticipated to grow by 400 million people. This increase in population will necessitate greater food production and the demand for water will only intensify. Given that agriculture consumes about 70 percent of the world's freshwater supplies, helping farmers grow more food with less water is one of the best ways to protect biodiversity, people, and economies dependent on these systems.

Agriculture plays a huge role in India, covering 160 million hectares of cultivated land. The country ranks second in global farm output and approximately 50 percent of the population is employed in the agricultural sector. Consequently, Indian agriculture accounts for 90 percent of the country's water use and presently, over 40 percent of usable water for agriculture is lost due to inefficient farming practices and about 50 percent of useable rainwater is lost due to runoff.

Irrigation for agriculture currently comes from three different sources: rainfall, rivers, and groundwater. 39 million hectares are irrigated by groundwater while the rest is dependent on either river-based canal systems or rainfall during the monsoon season. Climate change is becoming a reality with increasing droughts, unreliable rainfall, and rapidly depleting groundwater. With temperatures anticipated to rise between 1 and 3 degrees Celsius by 2050, the situation is expected to worsen.

Other challenges in India include the current landscape of agriculture which is made up of farmers who are unwilling to take risks and change the agricultural practices that have been passed down from prior generations. There is also a lack of clear water rights and groundwater management laws, creating a politically precarious environment for the introduction of new policies and programs.

NatureVest tasked our team of ten graduate students to design business models to incentivize adoption of water efficient agricultural practices by creating awareness, providing training, ensuring access to new technologies, and providing examples that demonstrate both water savings and financial return. The following is a short description of our business models which we elaborate on in the body of the report.

The focus region for the three business models is Uttar Pradesh, a state in northern India that maintains 15 percent of India's population and produces 20 percent of its food grains. With 75 percent of the net sown area in Uttar Pradesh irrigated, the region is severely water stressed. Uttar Pradesh is also the largest cultivator of sugarcane, our focus crop.

**Business Model 1 - Water Certification and Global Markets:** In this model, NatureVest would partner with an on-the-ground resource to create a water certification program for sugarcane farmers who implement water efficient practices. NatureVest will lend irrigation technologies and other resources while the local resource would provide training to farmers on water conservation techniques. Farmers

that meet water conservation targets over a set amount of time would be certified. Sugarcane produced by certified farmers will eventually be marketed and sold to environmentally-conscious consumers creating a demand source that will generate revenue for all parties in the supply chain while incentivizing farmers to employ water efficient practices.

**Business Model 2 – Solar Power for Irrigation and Income:** NatureVest would facilitate lending to farm cooperatives in conjunction with existing solar subsidies that offers farm cooperatives solar irrigation systems that are connected to the electricity grid. Whatever electricity the farmers produce and do not use for irrigation, they can pool together to sell back to the grid. This offers farmers an additional source of income. Since farmers can generate income from selling excess electricity, they will have an incentive to irrigate sparingly, which will lead to reduced water consumption. Similar models have been shown to double farmers' incomes, relieve financial burdens of the local utility, reduce greenhouse gas emissions (through use of solar pumps as opposed to typical diesel pumps), and mitigate the overexploitation of groundwater.

**Business Model 3 - Contract Farming:** This model proposes that NatureVest seeks partial ownership in a diversified mill and promotes contract farming for smallholder farmers in Uttar Pradesh. This would be in collaboration with a local non-profit, sugarcane farmers, mill owners, and an international Consumer Packaged Goods corporation. The local non-profit would facilitate training for farmers on water efficient growing methods and help them to implement these new strategies. The diversified mill would be incentivized to establish policies and requirements for sugarcane growers in their region. The corporation's local and global sales of sugar and associated byproducts will ensure income for farmers and the sugar mills as well as create a revenue stream for the investors.

The following report will include a detailed view of our business models and background research on the Indian agriculture sector, current sugarcane farming and irrigation practices, and the sugarcane market. The report will also provide information on political, regulatory and cultural influences that will enable or restrict adoption of our proposed models.

## B. ACRONYMS

<b>CPG</b>	Consumer Packaged Goods
<b>CSR</b>	Corporate Social Responsibility
<b>DISCOM</b>	Distribution Company in India
<b>FRP</b>	Fair and Remunerative Price
<b>GDP</b>	Gross Domestic Product
<b>MSP</b>	Minimum Support Price
<b>PPA</b>	Power Purchase Agreement
<b>SAP</b>	State Advised Price
<b>SPaRC</b>	Solar Power as Remunerative Crop
<b>SPICE</b>	Solar Pump Irrigators' Cooperative Enterprise
<b>SPI</b>	Solar Powered Irrigation
<b>SWOT</b>	Strengths, Weaknesses, Opportunities, and Threats
<b>TNC</b>	The Nature Conservancy
<b>UP</b>	Uttar Pradesh
<b>USDA</b>	United States Department of Agriculture

Key Terminology & Definitions for further terminology can be found in the appendix of this report, see **Appendix C**.

## C. ACKNOWLEDGEMENTS

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# *Introduction*



## 1. INTRODUCTION

The goal of this project was to produce three investable business models that promote water efficient agricultural practices to be implemented within a region of India for a specific crop while providing a return on investment. The main challenge was combating farmers' reliance on subsidized electricity while ensuring consistent access to water. Additionally, farmers' resistance to change was considered, since agriculture has several cultural implications. The water efficient practices being proposed will enable sustainable farming that enhances biodiversity, promotes water efficiency, and provides rural economic development.

In order to address the issue of water efficiency, a geographic region was identified where the business models being proposed could be piloted. To arrive at a focus region, the team considered three factors: 1) land under cultivation, 2) contribution of crop yield to India's gross domestic product (GDP), and 3) level of water scarcity. Research on the state of Uttar Pradesh (UP) showed the following about the state, which:

- Maintains 15 percent of India's population
- Has the largest area of land under cultivation in the country
- Contributes 20 percent of the country's total food grain production
- Has an agricultural sector GDP of 25 percent (of the whole state's GDP)
- Irrigates 75 percent of its net sown area
- Faces severe water stress

Given the three factors evaluated, and in consultation with the client, NatureVest, Uttar Pradesh was the state chosen for the focus of this project.



Figure 1-A. A sugarcane dealer being shaved by an itinerant street barber. (Jean-Leo Dugast 2002)



## 1.1 FOCUS AREA INTRODUCTION

The state of Uttar Pradesh lies in the Ganges (or 'Ganga') River basin, which originates in the Himalayan mountains, flows through the northern plains of India and drains into the Bay of Bengal (See Figure 1-B).

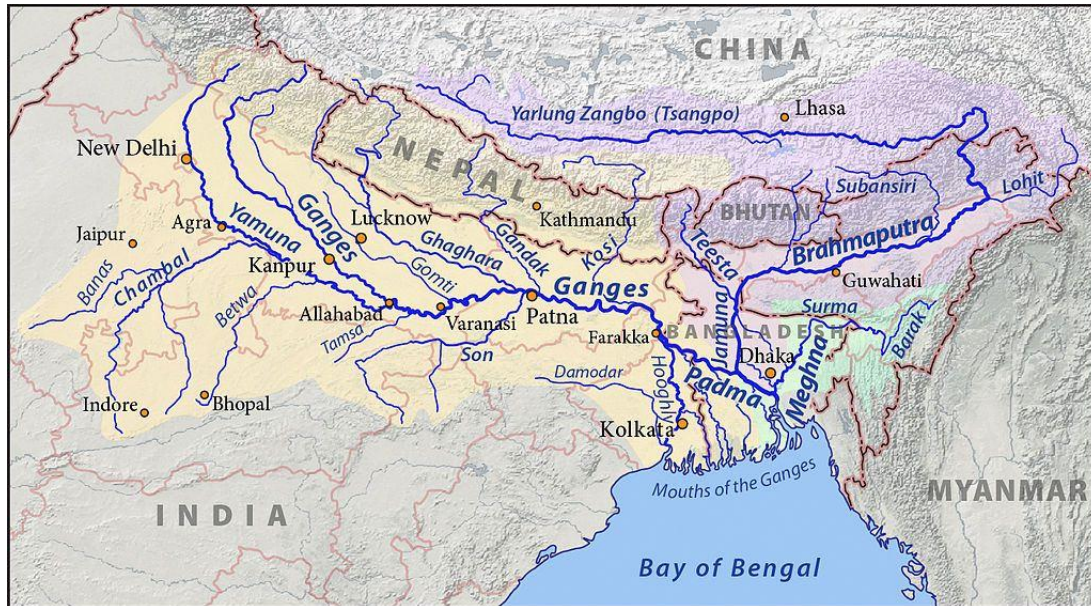


Figure 1-B. Drainage Basin of the Ganges (Pfly 2011)

Described in an ancient Hindu sacred text, the Mahabharata, as the 'best of rivers, born of all the sacred water,' it is regarded as a holy river in Hinduism (Cartwright 2015). For centuries, many civilizations have thrived on the banks of the river due to the presence of abundant water and fertile soil. Today, the river's extensive basin nurtures and supports a population of over 400 million people that dwell on the Indo-Gangetic plains (for reference, the entire United States population is 330 million as per the U.S Census Bureau, 2018).

### 1.1.1 THE ISSUE

With great potential for hydropower and navigable waters, the Ganges has long been a source of livelihoods for millions of Indians. Additionally, the river is a great source of irrigation, and while the presence of water for irrigation is essential to the country's advancement, over time, easy access to water has led to unsustainable and inefficient irrigation practices. These practices have depleted groundwater levels and led to extreme water stress in many districts in the region. ("Annual Report 2017-18" 2018)

Further, overexploitation of the river, diversion of its waters for irrigation and industry, agricultural runoff, and disposal of waste—which includes industrial, domestic, and ritual dumping of human remains from funeral pyres—have severely contaminated the river. These practices have also led to the loss of biodiversity and an increase in fluctuations in the hydrological cycle.

### 1.1.2 NARROWING THE FOCUS: SUGARCANE FARMING IN UTTAR PRADESH

After determining that the Ganges river basin, and specifically, the state of Uttar Pradesh, would be an ideal focus area within India, the team was then tasked with selecting a focus crop grown in UP. This crop would be one with high water intensity and with an attractive economic profile for potential investors. Based on both research and guidance by the client, the team arrived at sugarcane.



Figure 1-C. Sugarcane at a Market (ibtimes.co.in)

For further information on other analysis completed by the team to arrive at a focus area and crop, refer to the appendix of this report [See **Appendix B.2. “Focus Area: Uttarakhand vs. Uttar Pradesh”**; **Appendix B.3. Crops Considered**].

## 1.2 PROBLEM STATEMENT

Sugarcane farmers in UP face significant challenges, including water management, crop production, and reliable sources of revenue. The team has identified two key variables for sugarcane production that can be improved: water consumption and farming methods.

### 1.2.1 CROP PRODUCTION

Some sugarcane farmers in UP receive diverted water for irrigation from the Ganges River Basin, which runs northwest to southeast through the center of the state. However, pollution of this river is well documented and is not always a reliable source of water for agriculture [See Appendix B.1.3. “Current State of the Ganges”]. Therefore, farmers often rely on groundwater resources and rainfall from India’s monsoon season. Unfortunately, monsoon rainfall has become less predictable in recent years and groundwater resources are fast depleting [See 3.1.1 “Climate Change in India”]. Despite these trends, there is little evidence that farmers are working to reduce their crop water consumption through sustainable farming methods. On the contrary, electricity subsidies provide free power to farmers who then leave their electric-powered groundwater pumps on because access to electricity in rural areas is intermittent [See Appendix B.4.1.4. “Solar-Powered Irrigation Pumps”]. With no perceived movement to curb water consumption, farmers often employ inefficient irrigation practices, such as waterlogging, or flooding of their lands through surface irrigation. [See Appendix B.4.1.1. “Surface Irrigation”] While some of this water is returned to the groundwater and nourishes the soil, a significant amount is lost to evaporation.

### 1.2.2 SOURCES OF REVENUE

Uttar Pradesh sugarcane farmers typically sell their sugarcane production to local mills for further processing and distribution. The sales price farmers receive from mills is mostly determined by India’s central government [See 3.1.4 “Agricultural Subsidies”]. Since the government faces immense pressure to promise farmers a livable wage, the sales price that the sugar mills must pay farmers keeps increasing. Unfortunately, this mandated price is not directly linked to the broader sugarcane market’s supply and demand trends [See Appendix B.5.1. “Agricultural Markets”]. In recent years, as a result of this, sugar mills have accumulated stockpiles of inventory. This is partially due to a decline in sugarcane demand coupled with highly productive sugarcane growing seasons; this excess inventory leads to significant waste. Despite the growing stockpiles, Uttar Pradesh sugar mills continue to accept sugarcane from farmers, as they are required to do so by law. However, mills are often unable to pay these farmers for their production. Payments may remain outstanding for months or even past the next agricultural cycle, which hinders farmers’ abilities to purchase farm inputs for future production. Farmers continue to sell their production to sugar mills on credit because the promise of future payment outweighs the alternative.



A photograph showing a person wearing a dark cap and long-sleeved shirt, harvesting sugarcane. The person is using a tool to cut the stalks of the sugarcane, which are lying on the ground. The sugarcane stalks are dark brown with white nodes, and the leaves are green and long. The background is filled with more sugarcane plants.

# *Proposed Business Models*



## 2. PROPOSED BUSINESS MODELS

Further research led to the following key insights:

1. UP sugarcane farmers are dependent on agriculture subsidies.
2. Farmers are not incentivized to be water efficient, even as the region experiences drought and as groundwater resources continue to deplete.
3. As sugarcane supply outweighs the sugar demand, processing mills have trouble paying farmers and inventory goes to waste.

These insights were used as the basis for the three business models, providing a framework which helped to guide the development of the proposed solutions.

NatureVest requested the team to research and identify potential investment opportunities that could generate revenue while also supporting The Nature Conservancy's goal to protect global freshwater ecosystems. The business models are considered an introduction to investable ideas on which the client will conduct further research and due diligence. Each business model follows NatureVest's adapted version of Alexander Osterwalder's Business Model Canvas template **[See Appendix A. "Business Model Canvases"]**.

### 2.1 KEY PROBLEMS ADDRESSED BY THE PROPOSED BUSINESS MODELS

While the team's research uncovered several issues pertaining to sugarcane farming in UP, there are two key problems that each of the three business models seeks to address.

1. Sugarcane farmers use an extraordinary amount of water for their crop production. One of the primary contributors is that sugarcane is a highly water-intensive crop that requires a lot of irrigation [See "Water Intensity"]. Poor groundwater management coupled with heavily subsidized electricity has provided sugarcane farmers in Uttar Pradesh with unlimited access to groundwater and caused overexploitation of water resources through surface irrigation [See "Power Subsidy"]. Sugarcane farmers in Uttar Pradesh do not irrigate their crop more efficiently due in large part to the employment of traditional farming methods and the lack of education on the benefits of water efficient methods which have been found to increase farm yields and profits. Furthermore, there is limited capital available for farmers to invest in more water efficient practices, which often require additional labor and equipment.
2. Sugarcane farmers in Uttar Pradesh have low and unreliable incomes. The government-mandated sales price of sugarcane production does not provide farmers with sufficient net revenue [See "Minimum Support Price"]. Additionally, sugar mills pay for sugarcane production using credit, which may result in payment delays for several months or longer. This is because sugarcane supply outweighs sugar demand, and sugar inventory stockpiles are already too high

[See “ Market Overview”]. Finally, sugarcane farmers lack access to the global sugar market for sales of their production. (Eaton and Shepherd 2001)

These challenges present barriers for UP sugarcane farmers to maintain a sustainable income and quality of life. The following business models were specifically designed to address these key problems and are listed in no particular prioritization order.

## 2.2 BUSINESS MODEL #1 - CERTIFICATION OF WATER EFFICIENT FARMERS

The first business model is the development of a certification for UP sugarcane farmers who adopt water efficient farming practices. This model would promote water efficient farming methods and create measurable water conservation goals that farmers could achieve to become certified. Consumer packaged goods (CPG) manufacturers that source sugarcane from these certified farmers would market their products to environmentally-friendly consumers by branding their products with a certification label.

### 2.2.1 PROPOSED SOLUTION

To incentivize UP farmers to adopt more water efficient agricultural practices, the team proposes that NatureVest partner with a local non-profit organization to develop a water efficient certification program. This organization will train farmers to use more water efficient practices, including the adoption of drip or sprinkler irrigation [See Appendix B.4. “Water Efficient Agricultural Technologies”]

Water efficient certification may also be awarded to farmers opting for less water intensive sugarcane varieties, like *Birendra* [See 3.3.4 “Crop Varieties”], coupled with more effective management techniques that focus on soil moisture rather than soil wetness. Farmers will be required to meet measurable water reduction goals. After training is complete, farmers will receive NatureVest’s water efficient certification. Certified farmers will be granted access to sell their sugarcane production to mills that process sugar for multinational CPG corporations. The CPG corporations, for an annual fee, will be granted access to label their products with NatureVest’s water efficient certification which would enhance marketing toward environmentally-conscious consumers.

### 2.2.2 VALUE PROPOSITION

This business model creates a reliable revenue stream for UP sugarcane farmers while accomplishing NatureVest’s goal of creating a financial return for investors that is tied to water efficient farming.

### 2.2.3 CHANNELS

Sugarcane farmers will have different opportunities to improve water efficiency depending on the current sugarcane seed varieties being planted, soil management techniques being practiced, and



accessibility to irrigation technology. This model suggests that NatureVest partner with an on-the-ground non-profit organization to develop temporary physical structures that serve as both storage hubs for seed and technology inventory and also as a location for support staff. These hubs will be located nearby farm cooperatives.

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#### 2.2.4 BENEFICIARIES

The following is a list of all parties that may benefit from this proposed business model:

**Sugarcane farmers:** They will receive training on potential alternative crop varieties like “Birendra,” water efficient technologies, and growing methods that will help them achieve water efficient certification. Certification will attract new demand from those willing to pay a premium for environmentally-friendly products. The associated premium will allow sugar mills to earn enough revenue to pay the farmers promptly and directly. The new market demand for water efficient certified products will also engage a sustainability-minded customer base.

**Consumer Packaged Goods corporations:** They will receive a new environmentally-conscious product and a reliable supply of quality sugar from a trusted source, creating a more resilient supply chain. The sugar product could be a new revenue stream that will reach sustainability-minded customers.

**Skilled labor force for Uttar Pradesh:** Jobs will be created for dissemination of tools and training by on-the-ground field officers. Auditors will also be needed to conduct annual measurements of farmers’ water conservation and to determine whether they are meeting the water-efficiency certification requirements.

**NatureVest:** NatureVest will continue to meet The Nature Conservancy’s mission of conserving international lands and water through this water conservation business model. New positions may be required at The Nature Conservancy’s India division to support the implementation and maintenance of this project. Furthermore, this model will provide NatureVest with a new investment product for its investors.

**NatureVest’s investors:** They will receive a financial return on their investments when this water efficient certified sugarcane is sold to multinational corporations. Additionally, this model successfully aligns NatureVest’s financial investments with their values.

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#### 2.2.5 INITIAL CUSTOMERS

This business model proposes that NatureVest conduct a pilot test amongst a select group of sugarcane farmers who are located in the same community and who have similar cultivation practices. The intent of this test is to provide these farmers with a uniform solution that requires the same training and minimal unique resources. Additional value of selecting farmers within the same community is the development of ambassadors among the community who can champion the certification program. The

team's research suggests that new programs may spread more effectively when community leaders share the success of their experiences with their neighbors.

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#### 2.2.6 KEY METRICS

Three key metrics that are recommended to determine the efficiency of this model exist across business, social, and conservation objectives. They are as follows:

##### Water Efficiency Metrics:

- Year-over-year growth of water in wells under the same monsoon conditions
- Rainwater harvesting that would not exist without NatureVest's investment

##### Social Metrics:

- Direct jobs created including trainers and local drivers delivering alternate seeds and water efficient technologies
- Indirect jobs created including 3rd party certification auditors and operations support staff

##### Farmers' Financial Metrics:

- Revenue generated from price premium for sugarcane farmers who sell certified production vs farmers who sell uncertified production
- Increased sugarcane yields
- Revenue collected for sugarcane farmers who sell certified production vs farmers who sell uncertified production
- Net operating income for sugarcane farmers who sell certified sugarcane production vs sugarcane farmers who sell uncertified sugarcane production

##### Investors Financial Metrics:

- Number of participating corporations and their annual membership fees
- Principal and interest payments to investors

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#### 2.2.7 KEY PARTNERS

Key partners who will be directly linked to the business model include seed suppliers, irrigation technology companies, transportation and distribution firms, educational outlets, and processing and storage plants.

While this business model is unique in the way it proposes certifying sugarcane farmers on the merits of water conservation, there are some known international efforts to improve sustainable agriculture in Uttar Pradesh. A particularly well-known effort is called "Meetha Sona Unnati" [**See 2.4.11 "Case Study: Meetha Sonu Unnati Project"**], which involves a partnership between Coca-Cola, DCM Shriram (an operator of Indian Sugar Mills), International Finance Corporation, and Solidaridad (an international

developer of sustainable supply chains). The program provides training for farmers and uses a mobile van to spread knowledge around sustainable farming practices. Any of the companies involved in “Meetha Sona Unnati” would be potential key partners for NatureVest.

The Alliance for Water Stewardship is another potential partner for this business model [See 2.2.11 “Case Study: Alliance for Water Stewardship”].

Further due diligence on the viability of this business model may be conducted by contacting The Food and Agriculture Organization of the United Nations, the International Water Management Institute, and the Council on Energy, Environment, and Water.

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### 2.2.8 COST STRUCTURE

The costs of this business model can be categorized into two types of costs: fixed costs and variable costs, which are broken down further in the following:

- Fixed costs:
  - Salaries for field officers, trainers, and operational staff
  - Cost of physical water-technology that is implemented
  - Cost of seeds
  - Employee benefits
  - Local office supplies
  - Office utilities
  - Office rent
- Variable costs:
  - Local transportation fuel
  - Local food and lodging
  - Employee bonuses
  - Water-technology maintenance

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### 2.2.9 REVENUE STREAMS

Farmers will profit by selling their certified sugarcane at a premium to mills that supply to the targeted multinational CPG companies sourcing water efficient sugar. This model will create a revenue stream for NatureVest’s investors through the collection of an annual fee from participating CPG companies.



## 2.2.10 SWOT ANALYSIS

This section contains a SWOT analysis of the Certification of Water Efficient Farmers business model (Table 2-1).

Table 2-1. SWOT Analysis for Business Model 1 – Certification of Water Efficient Farmers

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"> <li>• Mitigates risk of delayed and/or non-payment from sugar mills to farmers</li> <li>• Increases access to modern irrigation technologies and water efficient practices for farmers</li> <li>• Improves farmer access to inputs</li> <li>• Creates income opportunity for farmers, sugar mills, CPG companies, and investors</li> <li>• Incentivizes water-efficient agriculture</li> <li>• Provides consumers with new environmentally-conscious products</li> </ul>	<ul style="list-style-type: none"> <li>• Requires significant cooperation and coordination amongst multiple entities (farmers, sugar mills, on-the-ground NGOs, CPG companies)</li> <li>• Difficult to measure if farmers are meeting water efficient thresholds</li> <li>• Promotes water efficiency; not necessarily water conservation</li> <li>• Cultural barriers to attempting to change farming practices</li> </ul>	<ul style="list-style-type: none"> <li>• Consumer preference toward eco-friendly goods continues to increase</li> <li>• Climate change continues to provoke governments and NGOs to promote eco-friendly programs</li> <li>• CPG companies raise additional investment capital to fund the program</li> <li>• Program has potential to be replicable across other Indian states</li> <li>• Leveraging the farm ambassador model to increase farmer interest in the program</li> </ul>	<ul style="list-style-type: none"> <li>• Consumer preference toward goods with reduced sugar may continue to increase</li> <li>• Limited consumer interest in premium-priced, certified CPG goods</li> <li>• Governments and NGOs can further promote programs supporting reduced sugar consumption</li> <li>• CPG companies may not be willing to pay a premium for water-efficient certified sugarcane</li> <li>• Farmers may not meet production requirements under the contract due to external factors like extreme weather, availability of water and energy, or illness</li> <li>• Farmers may have limited capacity to adopt new farming practices</li> <li>• Cultural barriers to attempting to change farming practices</li> </ul>

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### 2.2.11 CASE STUDY: ALLIANCE FOR WATER STEWARDSHIP

The Alliance for Water Stewardship (AWS)—of which The Nature Conservancy is a member—is an international partnership between businesses, non-profit organizations, and public entities. Partners agree to adopt practices that promote sustainable water use based on a universal framework that the group calls the “AWS Standard.” The AWS Standard can be applied across any industrial sector and claims to be the only framework that wholly complies with ISEAL Alliance, a global, sustainability-driven membership organization for credible sustainability standards. ISEAL includes world-renowned partners like Fair Trade and the Rainforest Alliance (“Members and Subscribers | ISEAL Alliance” n.d.).

The AWS Standard requires that site owners commit to the following steps:

1. Commit to water stewardship
2. Gather and understand water-related data
3. Create a water stewardship plan
4. Implement their plan
5. Evaluate performance
6. Communicate progress with stakeholders

The AWS Standard uses independent third-party auditors to confirm achievement of water stewardship and certify sites as “Core,” “Gold,” or “Platinum” based on a points system.

AWS claims that its certified members have stronger customer relationships, better investor confidence, improved brand perception, and easier discussion with regulators and lawmakers.

To date, there are zero certified sites in India and only four agriculture-related sites certified globally (Australia, Peru, Spain, and Tanzania). Nestlé Waters holds two certificates in India’s neighboring country, Pakistan.

NatureVest should consider leveraging The Nature Conservancy’s existing membership of the Alliance for Water Stewardship. NatureVest may consider adopting some principles of the AWS Standard to identify and audit water efficient farmer cooperatives. NatureVest may also consider using a similar points system to develop farmers’ lending terms.

## 2.3 BUSINESS MODEL #2 - SOLAR POWER FOR IRRIGATION AND INCOME

The second proposed business model offers sugarcane farmers solar-powered irrigation (SPI) systems connected to the utility grid, such that the farmers can sell any electricity produced by the system that is not used for irrigation to the grid operator. The electricity sales provide farmers with an alternative income source that is free from the inherent risks associated with pests and disease. Additionally, selling excess electricity will incentivize farmers to irrigate less, leading to reduced water consumption.

The model, which goes by the name SPaRC (“Solar Power as Remunerative Crop”), has been piloted since 2016 in the Kheda district in Gujarat in west India (Paranjothi and Misra 2017) [See Appendix B.4.1.4. “Solar-Powered Irrigation Pumps”]. Preliminary results from the pilot have indicated a positive impact on the livelihoods of the participating farmers (Raymond and Jain 2018) and similar projects have been planned in the states of Karnataka, Bihar and Gujarat (Verma et al. 2013).

### 2.3.1 PROPOSED SOLUTION

In this proposed business model, NatureVest will partner with a local non-profit to facilitate the investment in SPI systems for sugarcane cooperatives (“co-ops”) in UP. To be selected to participate in the project, farmers must be connected to the utility grid and must be able to pay the initial deposit required by the investor. Once a co-op has been approved, a local organization, in coordination with NatureVest, will provide the technology and coordinate the assistance needed to obtain a soft loan to finance the remainder of the costs.

Solar pumps will be installed on each of the co-op member farms and connected through a microgrid to a single evacuation point, so that the excess electricity produced on each farm can be pooled and sold directly to the grid. The farmer cooperative will enter a power-purchase agreement (PPA) with the state utility Uttar Pradesh Power Corporation Ltd (UPPCL) to sell the electricity to the grid. The overall electricity sales will be allocated to individual farmers based on their production and consumption that is tracked with energy meters installed on each farm.

In the Gujarat pilot, a solar PV system of 56.4 kilowatt-peak (kWp) was installed for a co-op of six farmers with seven acres of irrigable land. The system could potentially generate around 85,000 kWh energy annually, out of which some 40,000 was estimated to be required for irrigation while the remaining 45,000 could be sold to the utility. The farmers signed a 25-year PPA with the local state utility, simultaneously giving up their right to apply for electricity subsidies for the duration of the agreement (Paranjothi and Misra 2017) (Verma et al. 2013). In the first six months of the pilot, the farmer cooperative earned around 2257 USD in solar electricity sales. While the first six members of the cooperative only contributed 70.50 USD per kWp, after seeing the benefits from the project three additional farmers were willing to join with a contribution of 352.70 USD per kWp (Paranjothi & Misra 2017).

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### 2.3.2 VALUE PROPOSITION

The proposed business model offers farmers an alternative source of income that (unlike regular agricultural earnings) is not vulnerable to risks such as pests and disease. Moreover, the model improves farmers' irrigation access as solar power is more predictable and reliable than grid electricity.

The model also supports water conservation. When farmers receive a payment from the power generated by their solar pumps that is not consumed for irrigation, they have a strong incentive to irrigate sparingly, which leads to reduced water usage.

In addition to the direct benefits, the proposed model has broader environmental and economic benefits from the increased renewable energy generation and water conservation; moreover, solar pumps remove the need for diesel-powered pumps, thus reducing the overall greenhouse gas (GHG) emissions of agriculture.

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### 2.3.3 CHANNELS

The model will be operated through farmer co-operatives that farmers can join by paying an initial deposit. NatureVest will offer co-operative members solar-powered irrigation pumps using on-hand funds. The co-operatives, with support from NatureVest, will negotiate a PPA with the local utility company to sell the excess electricity production to the grid.

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### 2.3.4 BENEFICIARIES

The parties receiving direct benefits from the business model are the following:

**Sugarcane farmers:** The proposed model offers farmers a new source of income that is free from risks associated with agricultural income, such as crop disease. Moreover, selling electricity is significantly less labor-intensive than agriculture. The model has the potential to increase crop yields through more consistent irrigation, since solar power is more reliable than the subsidized grid electricity that is typically only available for a part of the day.

**Electricity offtaker:** The proposed business model alleviates the burden of the state utility that is required to offer free or reduced electricity to farmers. Participating farmers would likely give up their right to apply for the electricity subsidy in exchange for their PPA. The utility also receives additional renewable generation capacity. In the Gujarat pilot project, the utility received carbon credits for the solar power generated by the farmers (Shah et al. 2017).

**NatureVest:** NatureVest will continue to meet The Nature Conservancy's mission of conserving international lands and water through this water conservation business model. New positions may be required at The Nature Conservancy's India division to support the implementation and maintenance of this project. Furthermore, this model will provide NatureVest with a new investment product.



**NatureVest's investors:** The investors will receive a financial return on their investment in the form of interest payments on the loans from the cooperatives. Additionally, this model successfully aligns NatureVest investors' financial investments with their investment values.

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### 2.3.5 INITIAL CUSTOMERS

Because of the high upfront capital requirements of the proposed model, the team suggests initially implementing a pilot project with one farmer cooperative. The members of the cooperative should live in the same village and have access to the electricity grid. Furthermore, prospective members should meet the eligibility requirements for a loan to finance the investment and be willing to put down the initial contribution required from the cooperative members.

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### 2.3.6 KEY METRICS

The team recommends tracking the following environmental, social and financial metrics to monitor the sustainability and impact of the proposed model:

- Environmental Metrics:
  - Water conservation: Under same monsoon conditions, year-over-year growth of water in wells
  - Renewable energy: kWh renewable energy sold to the grid
  - Fossil fuel-based energy savings: kWh energy diverted from the grid through the use of solar powered pumps as opposed to the grid or diesel-powered alternatives
- Social Metrics:
  - Farmer investment in communities made possible by the additional income source
  - Number of jobs created in the support and maintenance service
- Farmer Financial Metrics:
  - Income from feed-in tariff
  - Percent change in crop yields
- Investor Financial Metrics:
  - Interest payments
  - Percent loan repayment

---

### 2.3.7 KEY PARTNERS

Key partners directly linked to the model include the electricity offtaker (UPCCL), technology provider, and system maintenance provider. Moreover, because of the high upfront capital costs the team recommends exploring potential partnerships for grants or additional investment capital.

A potential alliance could be formed with a non-profit or Corporate Social Responsibility (CSR) fund to increase the income to farmers from the model by offering environmental bonuses on each kWh power sold to the grid. In the pilot project implemented in Gujarat, the farmers received a water-conservation bonus and a green energy bonus of Rs. 1.00/kWh offered through partnerships with the International Water Management Institute (IWMI) and CGIAR's (formerly Consultative Group for International Agricultural Research) research program on Climate Change, Agriculture and Food Security CCAFS (Paranjothi and Misra 2017).

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### 2.3.8 COST STRUCTURE

The costs of this business model can be categorized into two types of costs: fixed costs and variable costs, which are broken down further in the following:

- Fixed costs:
  - 1-3 early-stage field staff who administer loans and carry out project management tasks
  - Upfront investment in solar pumps
  - Upfront investment in microgrid infrastructure
  - Employee benefits
- Variable costs:
  - System maintenance
  - Local transportation fuel
  - Solar pump maintenance
  - Microgrid infrastructure maintenance
  - Employee bonuses

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### 2.3.9 REVENUE STREAMS

The investor will receive revenue from the interest payments from the soft loans granted to the farmers.

### 2.3.10 SWOT ANALYSIS

This section contains a SWOT analysis of the Solar Power for Irrigation and Income business model (Table 2-2).

Table 2-2. SWOT Analysis for Business Model 2 – Solar Power for Irrigation and Income

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"><li>• Increases farmer exposure to new technologies</li><li>• Increases and diversifies income stream to farmers</li><li>• Improves access to irrigation as solar power is more consistently available than grid electricity</li><li>• Incentivizes water efficient irrigation</li><li>• Reduces farmer reliance on subsidized electricity as well as the subsidy burden to the utility company</li><li>• Adds renewable capacity to the electricity system of UP</li></ul>	<ul style="list-style-type: none"><li>• High upfront capital requirements</li><li>• Potentially slow to scale due to the high upfront costs</li><li>• Unreliable grid infrastructure can reduce potential electricity sales – electricity cannot be sold when the grid is down</li><li>• Significant land requirements for the solar panels</li></ul>	<ul style="list-style-type: none"><li>• Increased government incentives for solar power and solar irrigation can reduce capital costs</li><li>• Partnering with an NGO or CSR fund to offer farmers additional income on top of the feed-in-tariff, such as a water conservation bonus</li><li>• Program has potential to be replicable across other Indian states</li><li>• Leveraging the ‘farm ambassador’ model to increase farmer interest in the program</li></ul>	<ul style="list-style-type: none"><li>• Consumer preference toward goods with reduced sugar may continue to increase, decreasing market demand for sugar</li><li>• Although results from the pilot in Gujarat have been positive, the project has been heavily subsidized – similar results might not be realized in a less subsidized model</li><li>• New subsidies for renewable technologies can lead to the introduction of models that are more attractive to farmers</li></ul>

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### 2.3.11 CASE STUDY: SOLAR PUMP IRRIGATORS' COOPERATIVE ENTERPRISE IN DHUNDI

The International Water Management Institute (IWMI) and CCAFS developed a program for a cooperative in Gujarat in which farmers collectively sell their excess power to the local electricity company, not only reducing the utilities' transaction costs but also providing supplemental income for the individual farmers (Shah et al. 2017). In May of 2017, in the Gujarati village of Dhundi, the world's first Solar Pump Irrigators' Cooperative Enterprise (SPICE) completed its first year in operation. This project was supported by IWMI and CCAFS who offered the cooperative members green energy and water conservation bonuses alongside the SPaRC model. The farmers use solar energy generated by their pumps to irrigate their own crops and then pool the surplus energy which they then sell to the local power distribution company, known in India as DISCOM (an abbreviation for "Distribution Company in India"). This DISCOM provided the cooperative with a 25-year power purchasing agreement in exchange for which the farmers surrendered their rights to apply for the grid power connection subsidy for the same 25-year timeframe (Shah et al. 2017).

One immediate benefit to the farmers was the ability to use their pumps at will as the power was "uninterrupted, predictable, available during the daytime, and free of cost." Some farmers were initially concerned with the loss of arable land that the solar panels would cover but have found that it is possible to grow high-value crops, such as vegetables, under the elevated panels. The solar pumps have also transformed the Dhundi water market. In the past, 49 diesel pump owners sold water to 200 farmers; now, many of those farmers are buying from the solar operators instead, reducing their water prices dramatically. Concern has been raised that given the lesser cost, there will be more irrigation but since the solar providers are getting a water incentive and power buy back agreement, they may be less incentivized to sell water as a service. Moreover, the DISCOM has been able to decrease their grid stress, and the current power purchasing agreement set in place grants them carbon credits for solar power generated by SPICE. After the first year of operation, this project has been successful for all members involved and appears to be a model example. However, given the high upfront capital costs it may be challenging to be brought to scale (Shah et al. 2017).



## 2.4 BUSINESS MODEL #3: CONTRACT FARMING

The third model enables NatureVest to support the entire supply chain: from sugarcane cultivation to the consumer product retail shelf. This is done through a three-pronged approach. First, NatureVest will partner with an on-the-ground non-profit organization to educate and train farmers on how to be more water efficient. Second, NatureVest will invest in fractional ownership of a diversified mill in UP to develop sustainable production standards. And, third, NatureVest will broker a contract between the mill and a multinational CPG corporation.

### 2.4.1 PROPOSED SOLUTION

The proposed solution requires NatureVest to partake in three partnerships through the sugarcane supply chain.

First, NatureVest will partner with an on-the-ground non-profit organization. The organization will serve multiple roles. It will educate farmers on:

- Seasonal high-yield intercrops grown between rows of sugarcane [**See 3.3.5.2 “Sustainable Farming Method: Intercropping”**]
- Water efficient agricultural methods such as drip irrigation [**See Appendix B.4.1.3. “Drip Irrigation”**]
- Means of capturing and selling byproducts of sugarcane [**See 3.3.2 “Market Overview”**]
- Soil management techniques [**See 3.3.5 “Efficient Practices for Sugarcane”**]

The organization would also advise on selecting a local drip irrigation technology company. Lastly, the organization would facilitate dialogue with the local government to obtain subsidies for water efficient irrigation systems and sugarcane inputs.

The second partnership that NatureVest will partake in is with an UP diversified processing mill which produces multiple sugarcane-derived outputs. In this model, NatureVest will seek partial ownership of the mill. With an influential ownership stake, NatureVest can help set standards pertaining to the type of sugarcane and byproducts accepted for processing. The standards imposed upon farmers selling their crops to the mill would relate to water conservation and sustainable farming.

The third partnership will be between the NatureVest-owned mill and a CPG corporation. NatureVest will identify and broker a contract with a CPG corporation that is seeking higher resiliency around the sourcing of its sugar and related byproducts. The corporation would also be one that is sustainability-minded and striving for stronger environmental practices within its supply chain.

### 2.4.2 VALUE PROPOSITION

This model produces more water efficient sugarcane and byproduct production, enables sustainability-driven decision-makers to uphold standards at the mill, and secures the finances of the supply chain

through corporate funding. NatureVest accomplishes its goal of creating a financial return for investors that is tied to water efficient farming.

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#### 2.4.3 CHANNELS

This model seeks to reach Sugarcane farmers in UP who have perceived barriers to the global market by providing linkages to corporate buyers. NatureVest's partnership with an on-the-ground non-profit organization will foster the development of temporary physical structures that serve as both storage hubs for seed and technology inventory and also as a location for support staff. These hubs will be located nearby farm cooperatives and the diversified mill in which NatureVest has partial ownership.

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#### 2.4.4 BENEFICIARIES

The following is a list of all parties that may benefit from the proposed solution:

**Sugarcane farmers:** The farmers receive the opportunity to implement water-efficient agricultural practices such as drip irrigation and intercropping. Farmers are also provided with the opportunity for an enhanced income and facilitation of the sale of their crop production. Similar to Business Model 1, this model will lift the revenue of the diversified mill, enabling the mill to pay farmers more promptly than the time it currently takes, which can be several months or up to a year.

**Crop processing mill:** The mill that NatureVest invests in would receive water efficient, high quality sugarcane and byproducts. The mill would also receive a guaranteed demand source via contract with a CPG corporation.

**Consumer Package Goods corporation:** The CPG corporation receives a steady supply source of high-quality water efficient sugarcane cultivation and its byproducts. The corporation also receives a new source of income as it creates a market for environmentally-conscious products.

**Skilled labor force for Uttar Pradesh:** Jobs will be created for dissemination of tools and training by on-the-ground field officers.

**NatureVest:** NatureVest will continue to meet The Nature Conservancy's mission of conserving international lands and water through this water conservation business model. New positions may be required at The Nature Conservancy's India division to support the implementation and maintenance of this project. Furthermore, this model will provide NatureVest with a new investment product for its investors.

**NatureVest's investors:** Investors will receive a financial return on their investments when this water efficient sugarcane is sold to CPG corporations. Investors will also receive satisfaction of successfully aligning their financial investments with their values.

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#### 2.4.5 INITIAL CUSTOMERS

This business model proposes that NatureVest conduct a pilot test amongst a select group of sugarcane farmers who are located in the same community and who have similar cultivation practices. The intent of this pilot program is to provide these farmers with a uniform solution that requires the same training and minimal unique resources. Additional value of selecting farmers within the same community is the development of ambassadors among the community who can champion the certification program. The team's research also suggests that new programs may spread more effectively when community leaders share the success of their experiences with their neighboring communities, generating further traction when the program expands.

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#### 2.4.6 KEY METRICS

The key metrics suggested for evaluating the efficiency of the business model are as given below.

- Water-Efficiency Metrics:
  - Year-over-year growth of water in wells under the same monsoon conditions
  - Realized reduction in water use (improved technology, improved irrigation scheduling, regulated deficit irrigation)
- Social Metrics:
  - Number of jobs created
  - Number of indirect jobs
  - Number of farmers trained
  - Number of community outreach
- Financial Metrics:
  - Revenue generated for farmers from sales of sugarcane
  - Revenue generated from intercrop yields
  - Revenue generated to NatureVest from mill partnership for the sale of selling sugar and other byproducts in the global/local market
  - Net operating income for farmers who sell sugarcane via contract farming vs. farmers who sell to regular sugar mills

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#### 2.4.7 KEY PARTNERS

Key partners who will be directly linked to the business model include an on-the-ground non-profit that identifies seed suppliers, irrigation technology companies, transportation and distribution firms, educational outlets, and processing and storage plants.

NatureVest can also lean on the participants of the “Meetha Sona Unnati” project including Coca-Cola, DCM Shriram, International Finance Corporation, and Solidaridad [See 2.4.11 “Case Study: Meetha Sona Unnati Project”].

Further due diligence on the viability of this business model may be conducted by contacting The Food and Agriculture Organization of the United Nations, the International Water Management Institute, and the Council on Energy, Environment, and Water.

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#### 2.4.8 COST STRUCTURE

The costs of this business model can be categorized into two types of costs: fixed costs and variable costs, which are broken down further in the following:

- Fixed costs:
  - Initial capital investment in diversified mill
  - Machinery and equipment to implement water efficient practices
  - Legal fees for contracts with diversified mill and CPG corporation
- Variable costs:
  - Maintenance cost associated with machinery at the diversified mill
  - Transportation cost of seeds and technology to farmers
  - Training materials for farmers
  - Cost of fuel
  - Marketing products
  - Salary

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#### 2.4.9 REVENUE STREAMS

Farmers will profit by selling their sugarcane and sugarcane byproducts to the NatureVest-owned diversified mill, which is supplying processed production to a contracted CPG company.



## 2.4.10 SWOT ANALYSIS

This section contains a SWOT analysis of the Contract Farming business model (**Table 2-3**).

Table 2-3. SWOT Analysis for Business Model 3 – Contract Farming

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"> <li>• Mitigates risk of delayed and/or non-payment from sugar mills to farmers</li> <li>• Increases access to modern irrigation technologies and water efficient practices for farmers</li> <li>• Improves farmer access to farm inputs</li> <li>• Facilitates access to markets and supports the shift from subsistence farming to commercial farming</li> <li>• Provides consumers with new environmentally-conscious products</li> </ul>	<ul style="list-style-type: none"> <li>• Requires significant cooperation and coordination amongst several stakeholders throughout the sugarcane supply chain</li> <li>• Requires a diversified mill ready to sell ownership stake</li> <li>• High transaction and management costs</li> </ul>	<ul style="list-style-type: none"> <li>• Expanding the model through partnerships with additional diversified mills and CPG corporations</li> <li>• Consumer preference toward eco-friendly goods continues to increase</li> <li>• Climate change continues to provoke governments and NGOs to promote eco-friendly programs</li> <li>• CPG companies raise additional investment capital to fund the program</li> <li>• Program has potential to be replicable across other Indian states</li> <li>• Leveraging the ‘farm ambassador’ model to increase farmer interest in the program</li> </ul>	<ul style="list-style-type: none"> <li>• Consumer preference toward goods with reduced sugar may continue to increase</li> <li>• Farmers may not meet contract’s production requirements due to external factors like extreme weather, lacking water or energy access, or illness</li> <li>• Farmers may have limited capacity to adopt new farming practices</li> <li>• Cultural barriers to attempting to change farming practices</li> </ul>

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#### 2.4.11 CASE STUDY: MEETHA SONA UNNATI PROJECT

DCM Shriram, IFC, Solidaridad, and Coca-Cola have partnered to introduce the “Meetha Sona Unnati” project focused on training and capacity building of sustainable agriculture practices (Nowak 2017). They offer video documentaries to 8,000 farmers each month through the use of a Mobile Van Theater, a van that is equipped with an outside screen enabling them to show two to three films over a two-hour period that are related to sustainable sugarcane cultivation. In order to capture the attention of the farmers, the screenings usually happen after dinner, a time when farmers are resting rather than working. As part of the training, they encourage farmers to keep a drip diary and crop calendar to improve water-management practices (Dhawan 2017).

Solidaridad, an organization working in India with support from multinational food and beverage companies, supports smallholder farm production through modern cultivation practices that emphasize climate smart agriculture. They have developed a set of agronomic tools to save 20 billion liters of water while also increasing cane yields by as much as 20 percent. They promote water efficiency, improve productivity, and reduced input costs through tools that include trash mulching, composting, wide row planting, intercropping and the application of biofertilizers. By enhancing water efficiency and soil health these tools support biodiversity as well. The Meetha Sona Unnati project is being introduced over the next three years in Uttar Pradesh with the hopes to train sugarcane farmers who supply four DCM Shriram sugar mills across five districts of the state. Sustainability sourcing is a core part of Coca-Cola’s sustainability targets for 2020 and in 2016 the company sourced over 1 million tons of sustainable sugar (Baron and Poff 2004).





# *Background Research*



### 3. BACKGROUND RESEARCH

This section will outline the areas of background research explored to better understand agricultural issues throughout India, initially, and then eventually relating to Uttar Pradesh.

#### 3.1 RESEARCHING THE ISSUE

When researching the issues leading to water efficiencies in agriculture in India, the team came across three primary areas of interest: environmental, social, and economic. The environmental issues involve climate change, degradation of the Ganges River basin, and biodiversity. When looking at social issues, the team found that farmers are highly reluctant to change their practices in favor of more water efficient ones due to existing social, economic, and policy driven barriers. Finally, the existing system of agricultural subsidies provided by the central and state government in India has created inefficiencies despite the government's best intentions, especially with regards to the electricity subsidy.

##### 3.1.1 CLIMATE CHANGE IN INDIA

Climate change is expected to play a significant role in shaping the future of India's development. The elevated concentration of greenhouse gases in the atmosphere is projected to increase global average temperatures, with India likely to experience a 1 to 3 degrees Celsius rise in temperature. This is expected to have significant and interconnected effects on air, water, and soil in India (Mani et al. 2018).

Temperature is not all that will be affected. The World Bank anticipates that climate change will also influence India's water resources (World Bank 2013). The changing climate will lead to more unpredictable rainfall, resulting in more frequent floods and longer periods of droughts. Climate related changes to weather and rainfall can have disastrous effects for both agriculture and farmers in India.

Climate scientists project increased mean temperatures from global warming will likely lead to rapid ice melt from the Himalayas during India's agricultural off season, creating water shortages and droughts during times that farmers traditionally rely on this water for irrigation purposes (Lahiry 2018).

Furthermore, Intergovernmental Panel on Climate Change (IPCC) estimates rainfall variability coupled with increased mean temperatures could result in a 10-40 percent loss of crop in the Indian agricultural sector (Aggarwal 2008). With India's population expected to grow by 400 million people by 2050 (Guruswamy 2017), this loss of food production would have serious consequences for India and its ability to provide its citizens with access to sufficient nutrition.

##### 3.1.2 BIODIVERSITY AND FRESHWATER SYSTEMS

The frequency of droughts in India has increased over the last several years and is predicted by meteorologists to continue on the same track (Srinivasa Rao et al. 2015). While droughts have severe effects on agriculture, their impacts can also pervade society, the economy, and the environment. As no life on Earth can persist without water, humans, wildlife, livestock, plants and soil are all affected by



drought. These negative effects can extend to freshwater resources as well (Dhawan 2017). Freshwater resources refer to those that do not contain salt which is what distinguishes them from marine and other saltwater ecosystems. Freshwater ecosystems, such as the Ganges River, are dynamic and make up part of Earth's water cycle. They directly interact with rivers and streams, marine ecosystems, land resources and the groundwater beneath (Gibb et al. 2013). These ecosystems are not isolated but rather linked with one another and therefore, pollution in one catchment can have widespread environmental impacts (Baron and Poff 2004).

There are two main issues connecting agricultural practices to freshwater biodiversity. First, agriculture cannot exist without water. In 2014, World Bank data showed that agriculture consumes 70 percent of the planet's freshwater (See **Figure 3-A**). For India, it is even higher as agriculture water withdrawals account for 90% of the total water withdrawal (DTE Staff 2018).

### Globally, 70% of Freshwater is Used for Agriculture

Share of freshwater withdrawals by sector (%) in 2014

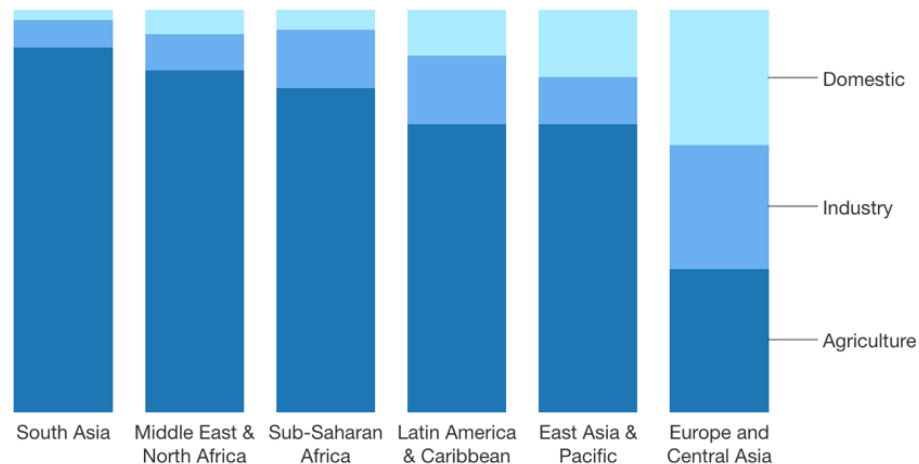


Figure 3-A. Freshwater Use for Agriculture (Khokhar 2017)

Based on this, the “challenge remains how to extract necessary water resources while protecting the natural ecosystem of freshwater resources” (Baron and Poff 2004). The second issue pertaining to freshwater biodiversity is the use of inorganic chemical fertilizers that add excess amounts of nutrients, namely nitrogen and phosphorous. An abundance of inorganic fertilizers applied to farmlands to increase productivity can enter into freshwater systems causing a phenomenon known as eutrophication. Eutrophication is the rapid introduction of excess nutrients into freshwater systems. This results in a depletion of oxygen in the water as the excess nutrients accelerate growth of surface algae beyond what is considered normal. The algae consume all the available oxygen resulting in a lack of oxygen in the water than can lead to hypoxia, or dead zones, where species cannot survive (“Nutrient Loadings and Eutrophication” n.d.). Proper watershed management, organic farming, and smart irrigation can curb groundwater depletion and maintain biodiversity within freshwater systems. In the face of climate change and a growing population, reducing water use in agriculture is a great opportunity to help feed the human population while also protecting nature and biodiversity.

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### 3.1.3 BARRIERS TO BEHAVIORAL CHANGE

This section describes barriers to behavioral change that would discourage farmers in the target community from participating in the implementation of the proposed business plans.

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#### 3.1.3.1 SOCIAL BARRIERS

Agriculture in India is not just a mere profession but instead is a cultural way of life which has been practiced for many centuries. Currently, 50 percent of India's population is employed in some form of agriculture (Dhawan 2017) and agriculture makes up 17.5 percent of India's GDP (Ahmad, Sinha, and Singh 2018). Given the dependency of the Indian economy upon agriculture, research and development in new approaches and technologies are essential to ensuring growth in the industry. These consist of both traditional as well as scientific approaches, which when employed correctly, can increase productivity without exploiting scarce resources. Despite the emergence of new approaches, there are many barriers to implementation due to deep-rooted traditional practices. The team found that certain features of society and culture might act as barriers to change in traditional practices when exploring alternative business models to improve agricultural water efficiency.

Research shows that rural societies look at new agricultural methods with indifference and suspicion (Oakley and Garforth 1983); farmers consider the older practices to be the best due to respect for elder generations as well as age-old traditions. Often times, villagers consider new or foreign practices as benefits to those introducing them rather than the farmers themselves, driving skepticism and disinterest. It was also found that Indian farmers highly value their leisure time, potentially causing a hindrance to the introduction of labor-intensive agricultural practices like drip irrigation and intercropping (Oakley and Garforth 1983). Given this perspective, the team found it essential that NatureVest educate farmers in the target communities about the benefits of the practices for the farming community themselves, emphasizing the needs of the farmer over the interests and benefits for potential investors.

Also, communities play an important role in reinforcing these traditional agricultural approaches. Therefore, individual farmers trying to adopt modern agricultural practices might be looked down upon and treated differently. This would result in unwarranted fear among farmers preventing them from adopting new practices. Additionally, due to lack of education and illiteracy, farmers are often unable to take advantage of the new technical or financial services available to them. The team concludes that it would be better to target and propose the new practices to a larger number of farmers or farm coops across a community to discourage isolation of individual farmers that agree to participate.

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#### 3.1.3.2 ECONOMIC BARRIERS

The rise in agricultural input cost coupled with barriers to enter the global market has left farmers completely at the mercy of the domestic sugar market. Smallholder farmers are the most vulnerable to market shifts and face the biggest hurdles as they lack the means to afford modern technology and therefore often have the lowest yields. In eastern UP, 75 percent of the farmers are considered

smallholder farmers with average land holdings of up to 2 hectares. These farmers are unable to generate sufficient funding to invest in new technologies that may help them to adapt to the market (Khan 2014). They also have less potential to bear risk due to their lack of financial resources, lack of external support, and intense competition from larger farms (Tripathi and Agarwal 2015). One option that could help farmers to compete with large-scale farms is consolidation; however, onerous leasing laws have prevented the ease of such transactions.

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#### 3.1.3.3 POLICY BARRIERS

Approximately 25,000 hectares of the overall 355,000 hectares of cultivated land in India, is rainfed; given this, the majority of cultivated land depends on groundwater resources (National Innovations on Climate Resilient Agriculture n.d.). However, the subsidies on electricity and water have not been beneficial from a water conservation perspective. A study was done to measure the impact and found that a 10 percent decrease in subsidies would reduce groundwater extraction by 4.3 percent. Despite the benefits to water, there are tradeoffs for the farmer. This decrease in subsidy would cost farmers 13 percent in agricultural revenues. As such, farmers may be resistant to changes in this policy and reluctant to use the water efficient business models proposed. (Badiani and Jessoe 2011)

However, despite the above constraints, the team believes that if the right environment is created and farmers are provided with training, infrastructure, technology, and financing, the proposed models will succeed. Success can be measured through agricultural productivity, enhanced food security, and an increase in income and quality of life for the farmers involved (Tripathi and Agarwal 2015).

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#### 3.1.4 AGRICULTURAL SUBSIDIES

Given extensive subsidies like tax exemption, low interest loans, forgiveness of debt, crop insurance, farm inputs, and minimum support pricing, the Indian farmer should be well positioned. Instead, the central government has created a culture of dependence that is perpetuated by spending billions of dollars each year on subsidies that often do more harm than good for the farmer. Farm incomes average less than one-third of non-farm incomes; since they typically earn less than the minimum taxable amount, the Central Government has exempted farmers from income taxes. One article states: “Even as the Indian government lavishes subsidies on farmers, it has also suppressed their earnings by hampering exports, through outright bans for some crops, as well as failure to invest in the needed infrastructure” (Agarwal 2016).

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##### 3.1.4.1 MINIMUM SUPPORT PRICE

The Minimum Support Price (“MSP”), which is set by the Indian government, guarantees a set price for crops sold to the government with the intention “to protect [India’s] large population of poor farmers (Agarwal 2016).” Oftentimes, the MSP proves detrimental to farmers despite the government’s positive intention. First, it establishes a dependent relationship wherein smallholder farmers grow crops solely to get the minimum guaranteed price rather than choosing an ideal crop based on the given climate or

water resources. In 2016, the Indian government spent 16 billion USD to purchase crops like wheat, rice, sugar and cotton at guaranteed prices to support the high population of poor farmers (Agarwal 2016). Moreover, most of the crops receiving the MSP are highly water consumptive, leading to inefficient use of resources and exacerbating India's water stress. The MSP also often leads to a surplus supply, falling prices, and little incentive for crop diversity. The government often ends up buying more produce than they need, requiring them to sell the commodity at a loss or allow it to waste away in a government warehouse. At times when there is a surplus, the government will unexpectedly dump commodities into the international markets, affecting the global market price and angering other producers. The Central Government spends around 30 billion USD a year on direct aid to agriculture while simultaneously depriving farmers of 40 billion USD by depressing domestic crop prices (as compared to the international market), suppressing earnings, and hampering exports through bans on certain crops (*The Economist* 2018). This extra spending on agriculture subsidies means the government is failing to invest in much needed infrastructure improvements that could reduce inefficiencies and boost yields (and therefore, farmer revenues and agricultural GDP) (Agarwal 2016).

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#### 3.1.4.2 POWER SUBSIDY

The underlying cause of India's water issues is the free electricity subsidy which gives farmers unlimited—yet unreliable—access to electricity. Since the flow of electricity tends to be more consistent at night, farmers leave their pumps on overnight in the event that power comes online, leading to flood irrigation, over-watering, and groundwater depletion. The cost of this subsidy alone is exorbitant; from 2013-2014, the agriculture power subsidy cost the government close to 10 billion USD, a figure that continues to rise (A. G. & S. Agrawal 2015).

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#### 3.1.4.3 SOLAR PUMP SUBSIDY

Currently, more than 9 million diesel pumps, which are both expensive to run and carbon intensive, are being used in India. In order to offset environmental issues associated with diesel pumps and to promote water efficiency, the government has introduced solar powered pumps used for irrigation with a plan by the Central Government to give capital subsidies for 100,000 solar pumps over five years. The central and state governments are promoting solar pump subsidies by offering up to 90 percent of the initial capital cost, leaving the farmer in charge of 10 percent. For solar pumps to be successful, however, they should be packaged with energy and water conservation measures because on their own, they fail to address the underlying issue of water stress. (Dhawan 2017) [**See Appendix B.4.1.4. "Solar Powered Irrigation Pumps"**]

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#### 3.1.4.4 NEED FOR CHANGE?

India's subsidy policy has long been challenged by many organizations; for example, the World Trade Organization critiques the fact that the policy to subsidize commodities (as a food security measure) has been a point of contention between India and the developed world. If for no other reason, the government should reduce the amount it gives in subsidies to alleviate its growing debt. However,



government officials are not relenting on subsidies despite their political nature, as the government believes encouraging agricultural productivity and better farming practices is part of their farm-welfare program that includes a five-year commitment to doubling farmers' incomes (Agarwal 2016).

The team believes that the Indian government cannot accomplish this ambitious target alone; therefore, corporate involvement is recommended. In 2014, India was the first country in the world to enact a law requiring corporate social responsibility (CSR). Any company with annual revenues of 10 billion rupees or more (approximately 140 million USD) are compelled by law to donate 2 percent of their net profit to charity. "One of the challenges for the corporate sector is finding credible partners and good projects that they can support" (Balch 2016). The team believes this law provides ample opportunity for NatureVest to partner with local corporations and enact positive environmental and social change. Collaborative efforts could influence overall changes in the farm-welfare program and create opportunities for Indian farmers in UP.

### 3.2 FOCUS AREA OVERVIEW: UTTAR PRADESH

Uttar Pradesh is a state in the northern part of India (See **Figure 3-B**) flanked by the Himalayas and bordering Nepal. It is largely composed of fertile alluvial plains watered by the Ganges and Yamuna Rivers. It is the most densely populated state within the country with more than 200 million inhabitants (Kopf and Varathan n.d.), and the 4th largest Indian state, covering 29.44 million hectares (See **Figure 3-C**). Agricultural and service sectors drive the economy in Uttar Pradesh which contributes to 8.24 percent of India's total GDP (*The Hans India* 2018)



Figure 3-B. Map of India, Highlighting UP (VectorStock 2018)



Figure 3-C. Map of UP Districts (Government of India 2011)

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### 3.2.1 AGRICULTURAL SECTOR

UP contributes 20 percent of India's total food grain output (India Brand Equity Foundation 2018a) and is the largest producer of wheat and vegetables in the country. Other major produce includes rice, maize and pulses. It is the largest producer of sugarcane in the country grown extensively in the western part of the state, accounting for about 145.39 million tonnes or 41.3 percent ("Agricultural Statistics at a Glance" 2017) of the total production. The export of agricultural commodities in 2017-18 stands at 2.83 billion USD (India Brand Equity Foundation 2018a). The state government is also actively promoting the use of technology to enhance online marketing of produce by linking over 100 Agricultural Produce Market Committees (APMCs) with the electronic National Agriculture Market (eNAM). Further information on the Indian agricultural sector can be found in the appendix of this report [See Appendix B.1. "India Agricultural Overview"].

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#### 3.2.1.1 LAND USE FOR AGRICULTURE

Of the total 29.44 million hectares, the total cultivable area available is 4.14 million hectare or 82.1 percent of total geographic area but the net sown area is only 68.5 percent of the cultivable area (Department of Agriculture & Cooperation Mechanisation & Technology Division n.d.). UP has a cropping intensity of 153 percent with a gross cropped area of 25.4 million hectares (Indian Council of Agricultural Research n.d.). Around 35 percent of the cropped area is sown more than once. Out of the total 23.82 million land holdings, 78 percent are marginal farmers, 13.8 percent are small farmers and 8.22 percent of farmers have land holdings over 2 hectares (Department of Agriculture & Cooperation Mechanisation & Technology Division n.d.)

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#### 3.2.1.2 WATER USE FOR IRRIGATION

UP is divided into four economics zones: Western UP, Central UP, Eastern UP, and Bundelkhand. With the exception of Bundelkhand, which lies in the dry Vindhyan plateau, the other zones fall under the fertile alluvial plains of the Ganges.

The annual rainfall across UP varies greatly and is concentrated within four months (the monsoon season) causing a shortage of rainfall in the other months. Moreover, the annual average rainfall can vary greatly from 1700 millimeters per year falling in hilly areas to 840 millimeters falling in the Western UP zone (A. K. Singh et al. 2017). UP may seem like a water rich state due to the presence of the Ganges River and its corresponding canal systems, but it is in fact severely water stressed. The UP government has already declared several districts drought hit and identified others which are drought prone (WaterAid 2016).

Further, groundwater is fast depleting due to unsustainable use and indiscriminate depletion. The demand for water is also soaring due to the growing population and high population density (Census of India 2011 n.d.). The quality of the water in the state is negatively affected by industrialization, modern agricultural practices, and sometimes even cultural practices. In some areas, groundwater exploitation



has led to water table stress. In other areas, surface water management in shallow water areas has led to increased waterlogging and soil salinization.

Over 60 percent of small and marginal farmers resort to purchasing water for irrigation, most of which is sourced from local groundwater. (Jain and Shahidi 2018). 80.3 percent of the net sown area in UP is irrigated by various methods, which are divided into the following: (Department of Agriculture & Cooperation Mechanisation & Technology Division n.d.):

- Tubewells that pump groundwater account for 66.94 percent
- Canals account for 25.18 percent
- Other means account for 7.88 percent

### 3.2.1.3 COOPERATIVE SOCIETIES

Cooperative societies play a significant role in the growth of the Indian economy and especially the agricultural sector. Cooperative societies came about in India in the latter half of the 19th century (G. K. Sharma and Khan n.d.), largely in response to the financial need of farmers in rural areas seeking investment capital for critical farming activities such as seeding and harvesting. Prior to the introduction of cooperatives, farmers were solely dependent on regional moneylenders, leaving farmers vulnerable to exploitation. Today, most farmers' financial needs are handled by cooperative societies, which are estimated to offer roughly 46 percent of rural credit (Mahal and Adkar 2016). Beyond lending programs, agricultural cooperatives have been lauded as a means of encouraging massive-scale agricultural manufacturing while improving network cooperation and fairness.

The legal basis for cooperatives was provided through the enactment of Cooperatives Credit Societies Act of 1904 (Sapovadia and Patel 2012), which stated that apart from meeting credit requirements, cooperatives ("co-ops") are also meant to perpetuate development through the encouragement of mutual support amongst co-op members. Over time, they have evolved as an integral part of the Indian agricultural business framework for credit delivery. Co-ops, which are based on the values of equal opportunity, self-help, responsibility, democracy and unanimity, can be broken down into the following categories:

1. **Marketing cooperatives** market farmers' produce such as sugarcane, coffee, maize, beans, and livestock. Members sell their produce through their cooperative and benefit from economies of scale, resulting in fairer prices for their produce.
2. **Consumer cooperatives** provide goods and services to their members at competitive prices.
3. **Producer cooperatives** provide a forum for members to work together to produce or manufacture a product and market it.
4. **Financial cooperatives** provide financial services through savings and credit cooperatives, cooperative village banks, and cooperative banks.
5. **Service cooperatives** provide services to co-op members, including housing, health care, day care, water, power and energy. Service cooperatives provide these incentives for farmers at lower prices, better quality, and wider availability than otherwise offered by the larger market.

UP has 169 cooperative sugarcane development societies and 28 cooperative sugar mill societies registered and working under the sugarcane development department (Sugar Industry & Cane Development Department n.d.). These societies assist in operating 119 sugar mills in the state, as well as providing other services to sugarcane farmers in UP. Currently, there are 4.8 million sugarcane farmers registered under co-ops in UP. These co-ops provide technical assistance for sugarcane production, marketing, and help to maintain the coordination between farmers and mills. They also play an important role in ensuring that payments to farmers adhere to the rates set by the state government. These State Advised Prices (SAP) mandated by the state government are substantially higher than the Fair and Remunerative Price (FRP). In partnership with co-ops, state governments exercise control over supply and distribution of sugarcane. However, the central government regulates the sugar industry.

The relationships between the central and state governments, as well as the cooperative societies, provide a complex regulatory framework for sugarcane production in UP that will be relevant to NatureVest as they navigate the introduction of a new project in this region.

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### 3.2.2 CLIMATE CHANGE IN UTTAR PRADESH

As climate change becomes more of a reality, temperatures will rise, rainfall will become less predictable, and droughts will increase. These factors will adversely affect small and marginal farmers in Uttar Pradesh. According to the Uttar Pradesh State Action Plan on Climate Change 2014, agricultural productivity is likely to decline up to 25 percent in irrigated areas and up to 50 percent in rainfed areas (Department of Environment 2014). The state government is working to understand the vulnerabilities associated with a changing climate and further research the potential adverse effects on the state's agricultural sector. Already, the state offers farmers training on climate-smart agriculture, soil and water management, and methods to increase productivity. Farmers are encouraged to practice organic farming and diversify their incomes through intercropping [**See 3.3.5.2 "Sustainable Farming Method: Intercropping"**]. Given that efforts are already in place, NatureVest should be well poised to form partnerships with similarly minded organizations that have an established presence in Uttar Pradesh.

### 3.3 FOCUS CROP OVERVIEW: SUGARCANE

Sugarcane plays a particularly important role as a cash crop in the domestic sugar market in India which is one of the largest in the world. After Brazil, India is the second largest producer of sugar and 60 percent of the world's sugar is made from sugarcane. Sugarcane contributes to the employment of 45 million farmers in India and a "large mass of skilled and unskilled workers are also engaged in sugarcane cultivation, harvesting and ancillary activities." (Ahmad, Sinha, and Singh 2018).

Given the economic impact of sugarcane, as well as its significant water footprint, this crop was the desired focus for this project. This section will provide further background research on sugarcane.

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#### 3.3.1 CULTURAL SIGNIFICANCE

The first organized production of sugar began in India in 1000 BC. Trading of sugar started in the 5th century AD, when an Indian chemist found a way to crystalize extracted sucrose, making sugar much easier to transport. With this great discovery, sugar became a very expensive, and, thus, profitable, commodity in India ("Sugarcane - History and Facts of Sugarcane" n.d.).

In addition to the economic contributions, sugarcane also holds cultural significance in Indian festivals and rituals. *Devotthan*, or *Prabodhini Ekadashi*, is a Hindu festival celebrated predominantly by North Indian communities, including UP. This day marks the beginning of the sugarcane harvest. It is believed that offering the Gods freshly cut sugarcane will encourage them to create a good harvest. It is also serves as *prasad* within the household and community; *prasad* is a material substance of food that is a religious offering in both Hinduism and Sikhism. Sugarcane is seen as holding nutritional value in India, as it is also a source of several vital nutrients, including calcium, magnesium, potassium and iron; therefore, it is considered beneficial to have sugarcane on this particular day, which marks the change of seasons. It is also believed that this will result in numerous health benefits and will protect the body during the winter. Sugarcane holds deep meaning and cultural value for many North Indians, indicating that careful thought must be taken when recommending any changes to the existing sugarcane cultivation system (Goswami 2017).

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#### 3.3.2 MARKET OVERVIEW

This section will discuss the market for sugarcane, sugar, and other sugarcane-derived products.

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##### 3.3.2.1 SUGARCANE PRODUCTION

Sugarcane is an important driver of rural development (Solomon 2014). The industry supports over 6 million farmers and their families, workers and entrepreneurs of over 700 sugar mills, as well as a host of wholesalers and distributors spread across the country. Sugarcane generates around 1.1 percent of India's GDP, which is significant considering that the crop is only grown in 2.6 percent of the gross cropped area (Solomon 2016). Sugarcane production is expected to total 415 million tons by 2019,

reflecting a 5 percent increase from the previous year. USDA research reflects that this increase is driven in large part by a larger cultivation area and improved yields (Aradhey 2018).

There are two regions in India for growing sugarcane, the tropical area in the southern states and the subtropical area in the northern states. UP is part of the subtropical region that maintains 55 percent of the total sugarcane area and contributes 35 percent of the total sugar production in the country. In 2016, UP was the largest producer of sugarcane in India and the percentage of acreage under cultivation of sugarcane has recently increased. In fact, UP was one of the only states in the subtropical region at this time to show an increase in area of production and reduced instability in yield (Ahmad, Sinha, and Singh 2018).

In 2015-2016, UP produced 145.4 million tons of sugarcane, making up over 40 percent of the overall production of 352.2 million tons (“Status Paper on Sugarcane” 2017). The price of sugarcane is regulated both nationally and at state level. The central government sets a Fair and Remunerative Price (FRP) for sugarcane based on factors such as cost of sugarcane production, prices of other agricultural products, returns from sugarcane byproducts such as molasses and bagasse, consumer price of sugar, and reasonable margins for sugarcane growers (“Status Paper on Sugarcane” 2017). Moreover, several states assign State Advised Prices (SAP) to sugarcane that are usually 30-35 percent higher than the FRP, mostly because of political populism rather than market pricing (Aradhey 2018).

Aside from sugar, sugarcane is also used to produce alcohol (around 2.7 billion liters per year) and for power generation. In the future, emerging products—such as raw sugar and renewable energy generated from bagasse—are expected to present opportunities to the Indian sugarcane industry (Solomon 2016). Power generation holds significant opportunity in UP as the state has the potential to produce 27.05 million tons of usable bagasse annually, which could be transformed into 1.93 GW bioelectricity (Hiloidhari, Araújo, and Kumari 2018).

Major challenges for sugarcane agriculture include static crop yields that have around 70 tons per hectare (Solomon 2016); however, yields have recently improved, mostly due to broader adoption of higher-yielding cane varieties (Aradhey 2018). In UP, crop yields are slightly below the national average at 67 tons per hectare (“Status Paper on Sugarcane” 2017)

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### 3.3.2.2 SUGAR AND OTHER SUGARCANE BYPRODUCTS

In the last couple of years, India’s sugar production has been on the rise. In the marketing year (MY) 2017-2018, estimated production increased by 46 percent from the previous 2016-2017 MY to 32.4 million tons and is expected to continue growing, reaching the record level of 33.8 million tons in MY2018-2019. Sugar production figures include milled sugar, whose projected production in 2018-2019 will be 31.1 million tons, and *khandsari*, a partly refined sugar also known as muscovado, whose production in 2017-2018 is estimated to amount 560,000 tons.

Byproducts of sugarcane also feed into several small-scale industries and has brought about several changes in the region’s economy. Sugar and sugarcane fermented byproducts are important in making



and preserving various kinds of medicines like syrups, liquids, and even capsules. Sugarcane also provides a juice, which is used for making white sugar, jaggery (*gur*) and many by-products like bagasse and molasses (V. Kumar 2013).

As the largest sugar producing state, UP is forecasted to achieve mill sugar production of 11.2 million tons in 2018-2019, followed by Maharashtra and Karnataka with projected mill sugar productions of 11.0 and 3.9 million tons in 2018-2019, respectively. Data from the 2017 “Status Paper on Sugarcane” showing mill sugar production of the three largest producing states is presented in **Figure 3-D** below (“Status Paper on Sugarcane” 2017):

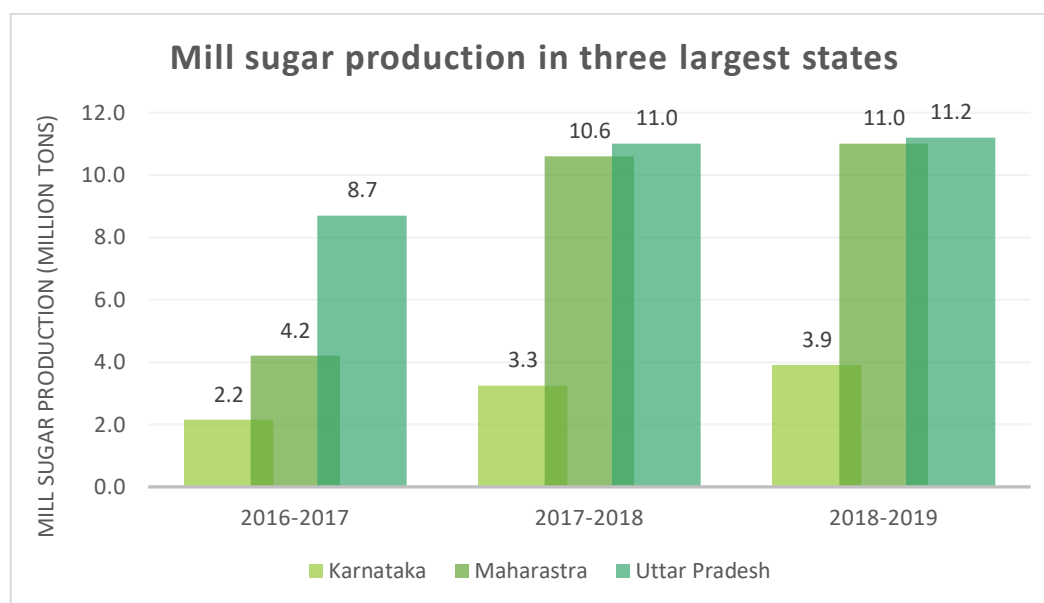


Figure 3-D. Mill Sugar Production in Karnataka, Maharashtra, and UP

Combined, these states contribute more than 80 percent of India’s total sugar production (“Status Paper on Sugarcane” 2017).

### 3.3.2.3 SUGAR CONSUMPTION

In India, sugar is a heavily consumed commodity and also a source of energy for the poor. Total consumption of sugar has increased steadily despite fluctuations in production. Urban consumption accounts for nearly 45 percent of the total white sugar utilization (“Status Paper on Sugarcane” 2017). Another important byproduct of sugarcane is *gur* (also known as jaggery), a less refined sweetener made of cane juice (Aradhey 2018). Jaggery is used to make desserts in major parts of South India and sugar itself is used in the preparation of several sweet dishes or mithai on various festive occasions. A slightly sweet and savory alcoholic drink called Falernum can also be made from sugarcane juice.

Most of India’s sugar production goes to domestic consumption. The consumption forecast for 2018-2019 is 27.5 million tons compared with estimated 26.5 million tons in 2017-2018. Exports are relatively small and were estimated to amount to 2 million tons in 2017-2018 and to go up to 6 million tons in

2018-2019, assuming normal market conditions. India also imports small amounts of sugar mainly from Brazil (Aradhey 2018).

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### 3.3.3 WATER INTENSITY

Sugarcane is a highly water-intensive crop; in India, sugarcane requires 1,500-2,000 mm water to produce 100 tons of millable cane, which translates to roughly 88 liters of water per one kilogram of cane. Due to the high water requirements, more than 96 percent of the land under sugarcane is irrigated, and in some states irrigation coverage is at 100 percent or approaching it. According to a study by NABARD and ICRIER, the water productivity of sugarcane in India is above the global average (5.2 kg/m<sup>3</sup> vs. 4.8 kg/m<sup>3</sup>) but lower than water-efficient sugarcane production in the other large producer countries South Africa (5.8- 7.8 kg/m<sup>3</sup>) and Thailand (5.8-6.5 kg/m<sup>3</sup>) (B. Sharma, Gulati, and Mohan 2018).

The irrigation requirements for sugarcane in India vary by region, being higher in the southern sugarcane producing states where the rainy season is shorter. UP is located on the northern sugarcane belt and has lower irrigation requirements than the two other largest sugarcane producing states Maharastra and Karnataka; however, because of the dry summers the overall water requirement in the region is higher ((B. Sharma, Gulati, and Mohan 2018); (“Status Paper on Sugarcane” 2017)). Sugarcane irrigation coverage in UP is approximately 95% and total water productivity is 4.8 kg/ m<sup>3</sup>, which is below the national average (B. Sharma, Gulati, and Mohan 2018).

According to a report by NABARD and ICRIER, the water efficiency of sugarcane cultivation could be improved in all the major sugarcane producing states, including UP. Moreover, although UP accounts for nearly half of India’s total land under sugarcane, due to low yield its production does not match the area proportion. More efficient water use could help bring crop yields to the same level with the other largest sugarcane producing states (B. Sharma, Gulati, and Mohan 2018).

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### 3.3.4 CROP VARIETIES

There are upwards of 33 varieties of sugarcane that are currently approved for cultivation in UP. These varieties include those that are tolerant to both drought and waterlogging, as well as those that are earlier-to-mature and more resilient to changes in weather.

One key variety, “Birendra” (CoLK 94184), was released for commercial cultivation in UP in 2016. This variety, which was developed by the Institute of Sugarcane Research (IISR), has a unique combination of two factors that are especially advantageous to UP cultivation: early maturity and high ‘ratooning,’ which is the ability of the plant “stubble” post-harvest to continue to provide output without replanting seeds. IISR estimates that the variety could generate yields of 75 to 80 tonnes per hectare for initially planted crop and an additional 70 tonnes over the course of the next 2-3 years from ratoon. In addition, the variety is highly tolerant to water logging, low moisture availability, pests and disease (*Indian Institute of Sugarcane Research*). Though the crop appears promising, as of late 2016, there was low conversion to this variety, providing an opportunity that could be introduced by NatureVest through

either of the team's recommendations of contract farming or water efficient sugarcane certification (Rawat 2016).

There are also genetically modified (GM) varieties being developed through the Indian Council of Agricultural Research (ICAR) and Vasantdada Sugar Institute (VSI). These GM varieties, similar to those developed by IISR, would also be less water intensive and more drought resistant than traditional sugarcane varieties employed in the region. However, the GM varieties may not be implemented in the short term due to regulations and lack of permission from the Genetic Engineering Appraisal Committee (GEAC) in the past for other GM crops (Mohan 2016).

The introduction of alternative varieties of sugarcane provides additional technological means for water efficient practices in sugarcane cultivation. These alternative seed varieties could be distributed as part of the water efficient practices that the team proposed in both Business Models 1 and 3. This would present NatureVest with the opportunity to drive traction in water-efficiency, since the crops themselves will be more resilient, earlier to mature, and less moisture dependent.

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### 3.3.5 EFFICIENT PRACTICES FOR SUGARCANE PRODUCTION

Sugarcane farming can be highly water intensive, especially for farmers in India who are not familiar with efficient methods and whose sole concern is maintaining or increasing production levels. Most sugarcane farmers in India follow a conventional practice of flood irrigation. They create extensive channels in their fields and directly flood the roots of the plant. Overtime this practice becomes ecologically destructive, resulting in waterlogging and increased soil salinity; issues often associated with soil sickness and that necessitate the use of synthetic fertilizers and pesticides, which themselves require increased amounts of water. This cycle is quickly escalated as chemical use is increased, creating a harmful pattern. However, as exposure to efficient practices increases, more farmers are implementing water saving strategies in their fields.

The team analyzed a number of different efficient irrigation methods that could be utilized in UP and are relevant to the proposed business models. Surface, sprinkler, and drip (also known as micro) irrigation methods were explored. Of the three, drip irrigation was found to be the most water efficient as it provides water directly into the plant root area at regular and frequent intervals. There is further detailed information on each of these methods in the Appendix of this report **[See Appendix B.4.1.1. "Irrigation Technologies"]**. Another means to reduce water use in sugarcane production is to minimize the number of furrows or irrigation channels. One case study in the southern Indian state of Karnataka illustrates this method.

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#### 3.3.5.1 CASE STUDY ON EFFICIENT IRRIGATION PRACTICES

In this example, a farmer named Suresh Desai designed and implemented a method to reduce water consumption by 75 percent for sugarcane plantations based on surface water irrigation (V. Kumar 2013). To preserve soil health and reduce irrigation, Suresh Desai adopted organic farming methods using natural rather than synthetics fertilizers to provide his crops with a natural growing environment. He

found that soil moisture, not soil wetness as was commonly believed, was vital to plant health and the practice of flooding the root zone was actually damaging the crop. Without permitting proper soil aeration, current practices are lowering soil fertility and making the plant more susceptible to disease.

In addition, Desai redesigned the irrigation system in his fields by reducing the number of water channels by half (see Diagram 1). The eliminated channel was filled with earth, becoming a bed of mulch, and increasing soil moisture retention. The additional moisture content allowed the soil to become rich in organic matter and the top layer was transformed into what he called a 'bio-film', "a rich, loamy layer of soil that is not only densely populated by earth fauna like earthworms, but one that has also been taken over by entire colonies of beneficial fungi aiding the decomposition process by enhancing the breakdown rate of the organic matter placed in the field." (Food and Agriculture Organisation 2010) This invigorated the soil and increased moisture retention allowing moisture to circulate evenly through areas that were not in direct contact with water (see diagram 2) and eventually reducing water consumption by 50 percent.

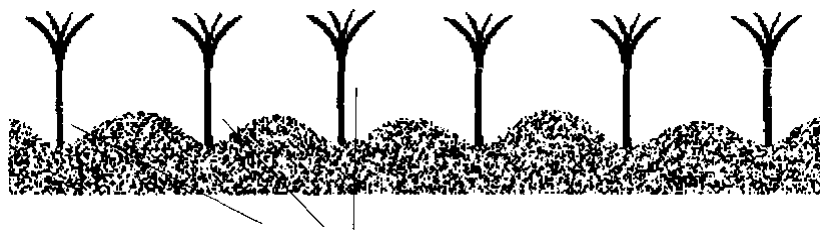


Diagram 1. Conventional sugarcane fields with plants located in water channels

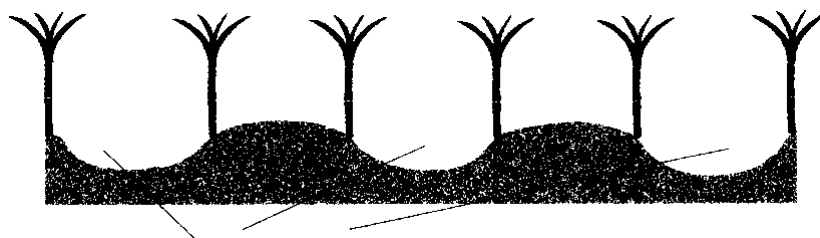


Diagram 2. Sugarcane field with plants located on both edges of a water channel

Desai eliminated an additional set of water channels three months later, bringing the number of channels down to just one whereas conventional farmers have four sets of water channels. This further reduction allowed for more soil moisture retention and Desai was able to bring his water consumption levels down an additional 25 percent for an overall savings of 75 percent (see diagram 3). Moreover, he grew plants, such as horsegram, that have a symbiotic effect with sugarcane, and also intensified microbial activity by introducing a blend of yeast, jaggery and cow dung in the water channels. This



created a microclimate that benefited the growth of earthworms, fungi and other beneficial microorganisms further improving soil health and improved biodiversity.

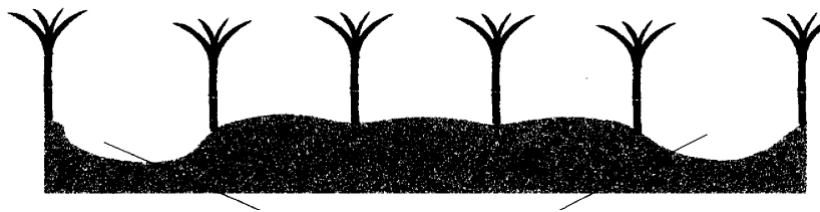


Diagram 3. Second stage: out of every five channels, now only two remain, but six rows of sugarcane plants continue to get moisture

Suresh's reasons for switching to sustainable practices were primarily economic in nature. "The understanding that organic materials were available and that the use of these could reverse the process of degradation of the family property pointed the way out." (Food and Agriculture Organisation 2010) His overall aim was to continue to produce a steady yield while employing sustainable and water efficient methods. The only drawback is that his yields are slightly lower than those of conventional farmers however, because his input, labor and water costs have decreased, he has still increased his overall profits.

#### 3.3.5.2 SUSTAINABLE FARMING METHOD: INTERCROPPING

The most promising sustainable farming method considered was intercropping. Intercropping is the practice of growing two or more crops on the same piece of land with defining row patterns in order to produce a higher yield per unit area over the same amount of time (S. N. Singh et al. 2018). Although intercropping has been practiced for centuries, current research and development in this field is less advanced than that for monoculture methods and therefore, intercropping is not commonly practiced. In March 2017, the central government announced a policy to double farmers income by 2022 through resource use efficiency, improvements in productivity, and diversification towards high value crops. Intercropping is one method to help achieve this target goal and sugarcane farmers should be encouraged to adopt intercropping (S. N. Singh et al. 2018). A more detailed description of intercropping, including suggested intercrops for sugarcane, can be found in the report's appendix [See **Appendix B.4.2. "Intercropping Crop Selection"**].

#### 3.3.5.3 SUMMARY

The team's research and case studies have shown that drip irrigation, intercropping, natural fertilizers, and strategic water channel design can reduce water consumption while increasing a farmer's net profits. NatureVest should consider integrating these four practices into the proposed business models when conducting further due diligence on the team's recommendations.

#### 4. CHALLENGES, RECOMMENDATIONS & NEXT STEPS

To gain a better perspective on the potential success of the models, the team conducted several external interviews with influential people working in Indian agriculture. These included research scientists, entrepreneurs, and other professionals. The team also talked with two staff members from TNC India who provided us with additional insight and information. Each interview conducted provided us with a different viewpoint based on the interviewee's research and experience.

Unfortunately, the team had only three months to complete this project. As such, there was not sufficient time to visit the region which would have given us a deeper understanding of both the barriers and opportunities faced by farmers in UP. For next steps, the team suggests that NatureVest, in coordination with TNC India, conduct further research in UP such as a needs assessment of farmers in the region.

Earlier in the report, the team referred to the CSR law that exists in India. This law mandates that corporations earning over 140 million USD donate two percent of their profits to environmental or social causes. The team emphasizes the opportunity that this provides for NatureVest to seek partnerships with corporations operating in India. While the proposed models create avenues for water efficient agriculture in India, there are several components within each that may require additional funding which could necessitate a partnership with a corporate entity.



A photograph of a man in a yellow shirt and blue jeans harvesting sugarcane. He is standing in a field of tall, green sugarcane stalks, using a machete to cut them. The background shows a clear blue sky. The word "Appendices" is written in white, italicized font across the center of the image.

# *Appendices*

## 5. APPENDICES

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### Appendix A. BUSINESS MODEL CANVASES

This section will provide the Business Model Canvas prepared for each of the three business models. The canvas is based upon the model created by Alexander Osterwalder and includes the following sections (and their respective descriptions):

- **Problem:** List your top 1-3 problems
- **Solution:** Outline the solution for each problem
- **Value Proposition:** Clear message of what you offer
- **Channels:** List your path to your customer
- **Beneficiaries:** List who benefits from this solution
- **Existing Alternatives:** List how these problems are solved today
- **Key Metrics:** List the key numbers that tell how your business, social, and conservation goals are performing
- **Key Partners:** List the individual partners needed for your solution
- **Individual Customers:** List the groups willing to pay for the value your solution creates
- **Cost Structure:** List your fixed and variable costs
- **Revenue Streams:** List your sources of revenue



## Appendix A.1. BUSINESS MODEL CANVAS #1 – CERTIFICATION OF WATER EFFICIENT FARMERS

<p><b>PROBLEM</b> List your top 1-3 problems</p> <p>1) <b>Sugarcane farmers use an extraordinary amount of water for their crop production.</b> Reasons include: sugarcane is highly water-intensive, poor groundwater management, no water efficient incentive, limited capital.</p> <p>2) <b>Sugarcane farmers in Uttar Pradesh have low and unreliable incomes.</b> Reasons include: sugarcane sales price is too low, sugar mills pay farmers on delayed credit, sugarcane supply exceeds sugar demand, global market access is limited.</p> <p><b>EXISTING ALTERNATIVES</b> List how these problems are solved today</p> <p>Refer to "Meetha Sona Unnati Project" and "Alliance for Water Stewardship"</p>	<p><b>SOLUTION</b> Outline the solution for each problem</p> <p>Partner with a local Indian non-profit org. to train farmers and provide certification to those achieving water efficient benchmarks.</p>	<p><b>VALUE PROPOSITION</b> Clear message of what you offer</p> <p>This business model creates a reliable revenue stream for Uttar Pradesh sugarcane farmers while accomplishing NatureVest's goal of creating a financial return for investors that is tied to water efficient farming.</p>	<p><b>CHANNELS</b> List your path to customers</p> <p>Farmers will receive sugarcane seed varieties, irrigation tech., and training from nearby temporary physical hubs developed in partnership with an on-the-ground non-profit org. Hubs will store seeds, tech. inventory, and support staff.</p>	<p><b>BENEFICIARIES</b> List who benefits from this solution</p> <p><b>Sugarcane farmers:</b> training, technology, seeds  <b>Multinational corporations:</b> new product line, revenue stream, and supply chain resiliency  <b>Skilled labor force for UP:</b> jobs for field officers and auditors  <b>NatureVest:</b> fulfillment of TNC's environmental mission, new jobs, new investment product  <b>NatureVest's investors:</b> financial return on investment, alignment of values with investments</p> <p><b>INITIAL CUSTOMERS</b> List the groups most willing to pay for the value your solution creates</p> <p>Pilot test amongst select group of sugarcane farmers in the same community with similar cultivation practices</p>		
<p><b>COST STRUCTURE</b> List your fixed and variable costs</p> <table border="0"> <tr> <td> <p><b>Fixed costs</b></p> <p>Salaries for field officers, trainers, and operational staff  Cost of physical water-technology that is implemented  Cost of seeds  Employee benefits  Local office supplies  Office utilities  Office rent</p> </td> <td> <p><b>Variable costs</b></p> <p>Local transportation fuel  Local food and lodging  Employee bonuses  Water-technology maintenance</p> </td> </tr> </table>		<p><b>Fixed costs</b></p> <p>Salaries for field officers, trainers, and operational staff  Cost of physical water-technology that is implemented  Cost of seeds  Employee benefits  Local office supplies  Office utilities  Office rent</p>	<p><b>Variable costs</b></p> <p>Local transportation fuel  Local food and lodging  Employee bonuses  Water-technology maintenance</p>	<p><b>REVENUE STREAMS</b> List your sources of revenue</p> <p>Farmers will profit by selling their certified sugarcane at a premium to mills who are supplying the targeted multinational CPG companies sourcing water efficient sugarcane. This will create a revenue stream for NatureVest's investors through the collection of a nominal annual fee from the participating CPGs.</p>		
<p><b>Fixed costs</b></p> <p>Salaries for field officers, trainers, and operational staff  Cost of physical water-technology that is implemented  Cost of seeds  Employee benefits  Local office supplies  Office utilities  Office rent</p>	<p><b>Variable costs</b></p> <p>Local transportation fuel  Local food and lodging  Employee bonuses  Water-technology maintenance</p>					

## Appendix A.2. BUSINESS MODEL CANVAS #2 – SOLAR POWER FOR IRRIGATION AND INCOME

<div>PROBLEM</div> <div>List your top 1-3 problems</div> <div><div>1) <b>Farmers irrigate in excess</b> because water and electricity are available for free. Electricity access is also spotty.</div><div>2) <b>Sugarcane farmers in Uttar Pradesh have low and unreliable incomes.</b> Reasons include: seasonality of agricultural incomes and risks such as crop disease, extreme weather and pests.</div></div>	<div>SOLUTION</div> <div>Outline the solution for each problem</div> <div><div>Offer farmers solar-powered irrigation systems that are connected to the utility grid. The farmers can sell any electricity produced by the system that is not used for irrigation to the grid operator on the basis of a power purchase agreement.</div><div>The electricity sales provide farmers an additional source of income that is free from the risks associated with income from crops. Solar power is also more reliable than the grid electricity farmers currently use, which improves irrigation access. Additionally, selling excess electricity will incentivize farmers to irrigate less, leading to reduced water consumption.</div></div>	<div>VALUE PROPOSITION</div> <div>Clear message of what you offer</div> <div></div>	<div>CHANNELS</div> <div>List your path to customers</div> <div>The model operates through co-operatives that farmers can join by paying an initial deposit. NatureVest will offer co-operative members solar-powered irrigation pumps with PAYG financing. The co-operatives will enter a power-purchase agreement with the utility company to sell excess electricity to the grid.</div>	<div>BENEFICIARIES</div> <div>List who benefits from this solution</div> <div><div><b>Sugarcane farmers:</b> new source of income, increased crop yields from more reliable irrigation access</div><div><b>Electricity offtaker:</b> reduced electricity subsidy burden, new renewable generation capacity, carbon credits</div><div><b>NatureVest:</b> fulfillment of TNC's environmental mission</div><div><b>NatureVest's investors:</b> financial return on investment, alignment of values with investments</div></div>
<div>EXISTING ALTERNATIVES</div> <div>List how these problems are solved today</div> <div>Refer to "Dhundi SPICE" project.</div>	<div>KEY METRICS</div> <div>List the key numbers that tell how your business, social, and conservation objectives are performing</div> <div>Year-over-year growth of water in wells under same monsoon conditions - kWh renewable energy generated - kWh renewable energy sold to the grid - farmer income from feed-in tariff – increase in crop yields – jobs in supporting services – increased farmer investment in communities – investor income from loan interest - loan repayment rate</div>		<div>KEY PARTNERS</div> <div>List the types of individual partners needed for your solution</div> <div><div>Uttar Pradesh state utility (UPCCL), electricity offtaker</div><div>Technology provider</div><div>NGOs for additional investment/grant funding</div></div>	<div>INITIAL CUSTOMERS</div> <div>List the groups most willing to pay for the value your solution creates</div> <div>Pilot project with one farmer co-operative. Co-operative members should live in the same village, have grid access, and meet the eligibility requirements for the technology loan.</div>
<div>COST STRUCTURE</div> <div>List your fixed and variable costs</div> <div><div><b>Fixed costs</b> 1 – 3 early-stage field staff who administer loans and carry out project management tasks Upfront investment in solar pumps Upfront investment in microgrid infrastructure Employee benefits</div><div><b>Variable costs</b> System maintenance Local transportation fuel Solar pump maintenance Microgrid infrastructure maintenance Employee bonuses</div></div>		<div>REVENUE STREAMS</div> <div>List your sources of revenue</div> <div>The investor will receive revenue from the interest payments from the soft loans granted to the farmers.</div>		

### Appendix A.3. BUSINESS MODEL CANVAS #3 – CONTRACT FARMING

<div>PROBLEM</div> <div>List your top 1-3 problems</div> <div><div>1) <b>Sugarcane farmers use an extraordinary amount of water for their crop production.</b> Reasons include: sugarcane is highly water-intensive, poor groundwater management, no water efficient incentive, limited capital.</div><div>2) <b>Sugarcane farmers in Uttar Pradesh have low and unreliable incomes.</b> Reasons include: sugarcane sales price is too low, sugar mills pay farmers on delayed credit, sugarcane supply exceeds sugar demand, global market access is limited.</div></div> <div><div>EXISTING ALTERNATIVES</div><div>List how these problems are solved today</div><div>Refer to “Meetha Sona Unnati Project” and “Alliance for Water Stewardship”</div></div>	<div><div>SOLUTION</div><div>Outline the solution for each problem</div><div><div>NatureVest supports the supply chain from sugarcane farming to CPG partnership. NatureVest partners with non-profit educate/train farmers on water efficient farming. NatureVest invests in a diversified mill to develop sustainable standards. NatureVest brokers a contract between that mill and a CPG corp.</div></div></div> <div><div>KEY METRICS</div><div>List the key numbers that tell how your business, social, and conservation objectives are performing</div><div><div>Year-over-year growth of water in wells under same monsoon conditions – realized reduction in water use - direct and indirect jobs created – number of farmers trained – community outreach metrics - revenue generated for farmers from sale of sugarcane – revenue generated from intercrop yields – revenue generated to NatureVest from mill partnership for the sale of selling sugar and byproducts – net operating income for farmers for contract farmers vs traditional farmers</div></div></div>	<div><div>VALUE PROPOSITION</div><div>Clear message of what you offer</div><div><div>This model produces more water efficient sugarcane and byproduct production, enables sustainability-driven decision-makers to uphold standards at the mill, and secures the finances of the supply chain through CPG corporation funding. NatureVest accomplishes its goal of creating a financial return for investors that is tied to water efficient farming.</div></div></div>	<div><div>CHANNELS</div><div>List your path to customers</div><div><div>Farmers will receive sugarcane seed varieties, irrigation tech., and training from the on-the-ground non-profit.</div></div></div> <div><div>KEY PARTNERS</div><div>List the types of individual partners needed for your solution</div><div><div>Key partners who will be directly linked to the business model include the on-the-ground non-profit that identifies seed suppliers, irrigation technology companies, transportation and distribution firms, educational outlets, and processing and storage plants.</div></div></div>	<div><div>BENEFICIARIES</div><div>List who benefits from this solution</div><div><div><b>Sugarcane farmers:</b> training, technology, seeds <b>Crop processing mill:</b> receive sugarcane/byproducts <b>CPG Corp:</b> new product line, revenue stream, and supply chain resiliency <b>Skilled labor force for UP:</b> jobs for field officers <b>NatureVest:</b> fulfillment of TNC's environmental mission, new jobs, new investment product <b>NatureVest's investors:</b> financial return on investment, alignment of values with investments</div></div></div> <div><div>INITIAL CUSTOMERS</div><div>List the groups most willing to pay for the value your solution creates</div><div><div>Pilot test amongst select group of sugarcane farmers in the same community with similar cultivation practices</div></div></div>
<div><div>COST STRUCTURE</div><div>List your fixed and variable costs</div><div><div><div>Fixed costs</div><div>Initial capital investment in diversified mill Equipment to implement water efficient practices Legal fees for contracts with diversified mill and CPG</div></div><div><div>Variable costs</div><div>Maintenance cost associated with machinery at diversified mill Transportation cost of seeds/tech to farmers Training materials for farmers Cost of fuel Marketing products Salary</div></div></div></div>		<div><div>REVENUE STREAMS</div><div>List your sources of revenue</div><div><div>Farmers will profit by selling their sugarcane to NatureVest's diversified mill, which is supplying the contracted CPG company. This will create a revenue stream for NatureVest's investors through the collection of a nominal annual fee from the participating CPGs.</div></div></div>		

## Appendix B. FURTHER BACKGROUND RESEARCH

### Appendix B.1. INDIA AGRICULTURAL OVERVIEW

India is one of the fastest growing economies in the world and agriculture continues to play a huge role in the growth of the Indian economy (PTI 2018). According to Census data from 2011, over 54 percent of the country's population is employed in the agricultural sector and other allied activities (Government of India 2018b). With the rise in population, changing diets, and agricultural lands being utilized by the energy sector, the strain on small Indian farmers is likely to continue or even worsen.

Meanwhile, impacts of climate change and unsustainable farming practices continue to dampen productivity and cause irreparable damage to the environment. Groundwater levels are fast depleting and rainfall is becoming unpredictable. In the wake of these long-term water problems, the central government has set out on an ambitious plan to divert India's perennial rivers for the purpose of irrigation. This proposed project has come under great scrutiny from the scientific community as it will have huge implications on the geography, ecology, communities, wildlife and agriculture (A. Pandey 2018).

The Indian agricultural landscape is dominated by small and fragmented land-holdings and cash-poor farmers who are highly dependent on government assistance. Average farm size has declined from 1.15 hectares per farm in 2010-11 to 1.08 hectares in 2015-16. Small farms are less economically viable as they incur greater transactional costs. There is a total of 146 million operational holdings today (an increase from 138 million in 2010-11) in the country. UP has the greatest number of farm holdings with 23.82 million holdings. Small and marginal holdings (0-2 hectare) constituted 86.21 percent of the total holdings, an increase from 84.97 percent in 2010-11 (Bera 2018b).

According to the agricultural census for 2015-16, the total operated area under agriculture has reduced from 159.59 million hectares in 2010-11 to 157.14 million hectares in 2015-16 (Government of India 2018a). The share of small and marginal operated area is 47.34 percent in 2015-16, up from 44.31 percent in 2010-11. This is due in part to the age-old inheritance laws of India. Typically, when farm land is passed down, land is equally divided between sons, thereby reducing the average size of holdings. In 2015-2016, semi-medium and medium operated holdings (2-10 hectares) accounted for 13.22 % percent of the operational holdings and 43.61 % percent of operated area. Large holdings (> 10 hectare) accounted for 0.57% percent of the operational holdings and 9.04% percent of the operated area. The large discrepancy between semi-medium and medium holdings, and large holdings further highlights the growing trend of small hold farming in India. With regards to ownership, individual holdings have grown by 5.04% percent, joint holdings by 7.07% percent and institutional holdings by 10.88 percent (Government of India 2018a).

Today's Indian farmer faces unprecedented and opaque challenges. Shrinking farm sizes, growing populations, climate change, and water insecurity are just a few of the many variables that make or break a farmer's livelihood.

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## Appendix B.1.1. LAND AND WATER RIGHTS

Depleting ground water levels and the general increase in water scarcity in India is likely to increase electricity charges associated with supplying water. Moreover, an increasing demand for hydroelectric power will shift water allocation and distribution, making water extraction and conveyance costlier.

Water rates play an important role in regulating water use and in ensuring efficient water management. Volumetric charging of water would prevent farmers from excessively using water for irrigation in order to avoid high water costs (Cornish et al. 2004). The 14th Finance Commission inter-alia recommended that “All States, irrespective of whether Water Regulatory Authorities (WRAs) are in place or not, consider full volumetric measurement of the use of irrigation water. States which have not set up WRAs, consider setting up a statutory WRA so that the pricing of water for domestic, irrigation and other uses can be determined independently and in a judicious manner” (Central Water Commission, Madaan, and Meena 2017). However, implementation of water pricing would be ineffective without prior establishment of a well-understood and legally supported system of water rights for users.

India does not have any explicit legal framework specifying water rights, even though various acts have some basis for defining some form of such rights. The Easement Act of 1882 made jurisdiction of all rivers and lakes the absolute right of the state (Saleth and International Water Management Institute 2004). While state’s absolute rights can affect the development and managerial aspects of water from the perspective of water use and its equity effects, it is the de facto control over water by actual users at the micro-level that is more important.

Individual rights to both surface water and groundwater are recognized only indirectly through land rights. Due to the ‘dominant heritage’ principle implied in the Transfer of Property Act IV of 1882 and the Land Acquisition Act of 1894, a land owner can have the right to groundwater as it is considered an easement connected to the dominant heritage (Saleth and International Water Management Institute 2004), i.e., land. In the case of canal water, the rights to access are limited to only those having access to land in canal command areas and these rights are only use rights and not ownership rights because irrigation acts do not allow the moving of canal water to non-canal areas. The control over groundwater at the field level is governed by a de facto system of rights as determined by farm size, the depth and number of wells, pumping capacity, and economic power.

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## Appendix B.1.2. DIVERSION OF THE GANGES RIVER FOR IRRIGATION

The Ganges River and its tributaries, especially the Yamuna, have been used for irrigation for decades. The river is channeled for irrigation either as runoff when the river is flooded or through developed canals when gravity pulls the water. Per Megasthenes, a Greek historian and ambassador who lived in India, irrigation canals date back to the 4th century BCE. Since then, the canal systems have been further extended and developed by the Mughals and the British (Lodrick and Ahmad 2018).



In the 1950s, India started the “green revolution”, the transformation of barren and forested land into heavily irrigated areas for agriculture. Although India became self-sufficient in food production during this period, the “green revolution” increased the exploitation of water resources, including the vast groundwater aquifers of the Ganges basin. The change in ground water recharge cycles due to the change in land use and unsustainable water abstraction for irrigation put a severe pressure on the local water resources. During this period, there was an expansion of the canal system, which further accelerated the development of numerous infrastructure projects.

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### Appendix B.1.3. CURRENT STATE OF THE GANGES

The cultivated area of the Ganges valley in UP benefits from the system of irrigation canals that has increased the production of cash crops such as sugarcane, cotton, and oilseeds. Canals are the source for 27.6 percent of the net irrigated area of the state of UP, most of which lie in the Ganga-Yamuna *doab* (*doab* meaning “land between two rivers”), Ganga-Ghaghara *doab*, and the western part of Bundelkhand region. The total length of canals is about 50,000 km, which provides irrigation to about 7 million hectares of the cropped area (“Information on Canals of Uttar Pradesh That Helps in Irrigation” n.d.).

Higher lands at the northern edge of the plain are difficult to irrigate by canal, and, therefore, groundwater must be pumped to the surface. In addition, large areas in UP are also irrigated by channels running from hand-dug wells. The system of irrigation is based on both gravity canals and electrically powered lifting devices. This new agrarian culture built around the irrigation apparatus of the Canal, has transformed the Ganges Basin in a machine-like landscape of production.

Although canals have been indispensable in the growth and development of the community and economy in the region, the team is of the opinion that diverting water from the Ganges has had inadvertent effects on the physiography, hydrology and biodiversity not only in the region but also further along the course of the river. The team presumes, the unregulated, easy access to water has also led to inefficient and unsustainable irrigation practices such as flood irrigation.

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### Appendix B.1.4. CURRENT AGRICULTURAL POLICIES AND MISSIONS IN INDIA

The increasing demand for food grains in India has necessitated the need to promote the growth of the agricultural sector. According to the 2018 budget, the central government has introduced several schemes aimed to double farmers' income by 2022. As of the end of the second quarter of 2017, the government has mobilized over 2.3 billion USD toward this goal (Government of India 2017). Some of these plans involve conservation of natural resources and sustainable agricultural practices.

The government created the National Mission for Sustainable Agriculture (NMSA) to increase productivity in the agricultural sector especially in rainfed areas. Under this mission, several initiatives have been proposed to focus on organic farming, efficient water-use, and soil health management.

Some of these include:

- **Soil Health Management (SHM):** Soil health cards are currently provided to farmers to help transition towards sustainable agricultural practices such as judicious use of resources. This is based on the knowledge that a better understanding of the soil leads to better crop yields. This process starts by taking soil samples from farms and testing them at research labs following to provide suggestions on improvements (“National Mission for Sustainable Agriculture” 2016).
- **Paramparagat Krishi Vikas Yojana (PKVY):** This is a sub-initiative of SHM that promotes organic farming in India (Ministry of Agriculture and Farmers Welfare 2018). Through this initiative, farmers are encouraged to form 10,000 clusters of 20 hectares each and take up organic farming methods. Each farmer will be given 283 USD per acre to obtain the seeds, tools, labor, and logistics necessary. The aim is to bring over 200,000 hectares of farmland under organic farming by the end of 2018.
- **Pradhan Mantri Krishi Sinchai Yojana:** This is a national mission to bring more farm areas under irrigation. It aims to improve farm productivity and ensure better utilization of resources. Through its four components, Accelerated Irrigation Benefits (AIBP), Har Khet Ko Pani (water for every crop), Per Drop More Crop, and Watershed Development, the government aims to have nearly 14 million hectares of farmland under irrigation by 2020 (NITI Aayog 2017).
- **Kisan Urja Suraksha Utthaan Maha Abhiyaan Yojana (Solar Pump Loan Subsidy Scheme):** This initiative aims to assist farmers procure solar pumps to generate power for irrigation (PTI n.d.). By utilizing solar pumps, farmers are able to send the excess power generation back into the grid and be compensated for this sale. In the 2018 budget, the central government has allocated 6.8 billion USD to fund the scheme for a period of 10 years (PTI n.d.). The central government will be subsidizing 60 percent of the total cost of converting from the existing diesel and electric pumps to solar pumps for all eligible farmers. Apart from this, another 30 percent of the cost can be availed in the form of institutional credit. The farmers will only incur 10 percent of the upfront cost to set up the pumps (IANS n.d.).

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## Appendix B.2. FOCUS AREA: UTTARAKHAND VS. UTTAR PRADESH

During the team’s initial research into potential focus areas for this project, the team narrowed in on two Indian states, Uttarakhand and Uttar Pradesh, before deciding to focus exclusively on UP due to its overall agricultural contribution, high sugarcane production, and large cultivated area.

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### Appendix B.2.1. INTRODUCTION TO UTTARAKHAND

In November 2000, the Indian states were reorganized and Uttarakhand (formerly known as Uttaranchal) was carved out of the Himalayan region of Uttar Pradesh. It shares international boundaries with China and Nepal.

Between 2011 and 2018, the Gross State Domestic Product (GSDP) grew by a Compound Annual Growth Rate (CAGR) of 10.86 percent, resulting in a total of 33.21 billion USD (India Brand Equity Foundation 2018b). This represents 1.3 percent of the total GDP of the country. Presently it is one of the fastest growing states in the country due to capital investments, generous tax benefits and conducive industrial policy. According to the 2011 Census, UP has a population density of 189 persons per square kilometer, with 10 million citizens living within UP’s 5.35 million hectares (“State Profile” n.d.).

The vegetation in Uttarakhand varies greatly by the elevation and climatic conditions in the state. Vegetation is sparse in the highest elevations of the state, closest to the Himalayas. These glacial areas eventually give way to Himalayan alpine and shrub regions followed by temperate subalpine coniferous forests (9800 to 8500 feet), temperate broadleaf forests (8500 to 4900 feet) and subtropical pine forests (4900 feet) as one moves closer to the plains (V. K. Pandey and Mishra 2015). The plains bordering the state of Uttar Pradesh consist of moist deciduous forests and grasslands which are being rapidly cleared for agriculture.

#### APPENDIX B.2.1.1. ECONOMY

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The Uttarakhand economy is heavily dependent on tourism, specifically religious tourism, as it is home to several pilgrimage centers. In 2017, domestic tourists amounted to 34.36 million people and foreign tourist arrivals had crossed over 0.13 million people (India Brand Equity Foundation 2018b). Electricity generation, namely hydropower, also factors into UP’s economy. Hydropower potential in UP is estimated to be 25,000 MW. For this reason, the state is being developed as an “energy state”.

As per the Ministry of Statistics and Programme Implementation, over 70 percent of the state is covered by forests. The value added from the primary sector, including forestry and logging in the year 2017-18 amounted to US\$ 534.78 million. The secondary sector, which includes manufacturing accounts for 49.23 percent of the value added to the GSDP of the state (India Brand Equity Foundation 2018b).

#### APPENDIX B.2.1.2. AGRICULTURE

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Agriculture in Uttarakhand primarily consists of sugarcane, rice, wheat, oilseeds, pulses and potatoes. The state's leading cash crop is sugarcane, which amounted to 5.98 million tons in the 2017-18 season (S. Kumar et al. 2018). Horticulture and medicinal plants are the other major focus areas. The state is home to over 175 rare species of medicinal and aromatic plants ("State Profile" n.d.). The state is home to almost all types of agricultural climate zones, which has made it easier for horticulture and floriculture to thrive commercially.

The state's landscape is 86 percent hilly terrain, which makes terrace farming common. This method of farming leads to low yield per hectare of crop. According to an industrial profile of Uttarakhand by the Ministry of Micro, Small & Medium Enterprises, over 80 percent of the total crop production are practiced on the plains ("State Profile" n.d.). The state government is encouraging the growth of the agricultural sector by introducing single window systems for the clearance of projects under central level missions such as the Horticulture Mission for North East and Himalayan States, National Mission on Food Processing, National Horticulture Board and Agricultural and Processed Food Products Export Development Authority (India Brand Equity Foundation 2018b).

The state government has been encouraging Agri-Export Zones (AEZs) for many fruit crops. Given that the region has an arduous terrain, the state government provides high incentives to cultivate in state. Currently, there are 16 Agricultural Produce Market Committees (APMCs) that have been integrated into the National Agriculture Market (eNAM) digital platforms in the state.

#### APPENDIX B.2.1.3. LAND USE FOR AGRICULTURE

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The net sown area in Uttarakhand is 766,000 hectares, which amounts to 14 percent of the total land area of the state. Uttarakhand has a cropping intensity of 161 percent with a gross cropped area of 1.2 million hectares ("Uttarakhand State Perspective and Strategic Plan 2009-2027," n.d.). Land holdings in Uttarakhand are more fragmented than in UP. Most agricultural cultivation happens for subsistence and for the family's own use. Since the land holdings are small the cost of cultivation is very high and this in turn translates into a high cost of labor, machinery and irrigation.

Land holdings in Uttarakhand can be grouped:

- 27 percent of cultivated holdings are under 1 hectare
- 51 percent of cultivated holdings are between 1 and 4 hectares
- 27 percent of cultivated holdings are greater than 4 hectares

Of the total land holdings, half are sub-marginal, 21 percent of total land holdings are between 0.5 and 1 hectare, 26 percent of land holdings are between 1 and 4 hectares, and 3 percent of land holdings are above 4 hectares in size ("Uttarakhand State Action Plan on Climate Change" 2014).

#### APPENDIX B.2.1.4. WATER USE FOR IRRIGATION

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The Tehri dam on the Bhagirathi River is one of the tallest dams in the world at 855 feet. This dam, which is located on the Bhagirathi River, is the highest dam in India and the main source of hydroelectricity, irrigation and municipal water in the state. The power generation has an installed capacity of 1000 MW, with a planned increase of up to 2400 MW (“Environmental Aspects Tehri Dam” n.d.).

Agriculture in the state is highly dependent on rainfall except in the plains where irrigation is predominant. The net irrigated area in the state is 345,020 hectares (Department of Agriculture & Cooperation Mechanisation & Technology Division n.d.).

In the state, farmers are reliant upon two types of watering means: rainfall and irrigation. Most of the agriculture in the Himalayan region is rainfed. The different sources of irrigation are canals (27.6 percent), tubewells (63.1 percent) and other methods (9.30 percent) (Department of Agriculture & Cooperation Mechanisation & Technology Division n.d.).

#### APPENDIX B.2.1.5. ISSUES

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Due to the terrain and the small and marginal land holdings, there is no economies of scale and the output per unit of input is low. The excessive use of fertilizers and overexploitation of groundwater leads to decreased fertility of the soil. The hilly terrain is susceptible to soil erosion due to excessive deforestation from terrace farming.

#### APPENDIX B.2.1.6. COMPARISON OF UTTAR PRADESH AND UTTARAKHAND

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A comparative analysis of both states was done to identify the focus area of the project.

Among the agricultural operational units, over 90 percent of the total number of operational holdings in UP and Uttarakhand are small and fragmented, with an average cultivated area of less than 2 hectares.

In all aspects of irrigation potential, Uttar Pradesh fares much better than Uttarakhand. Good irrigation management practices such as micro-irrigation and sprinkler systems are practiced in parts of UP. This existing practice could ease the introduction of good water management practices in other areas of the state.



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### Appendix B.3. CROPS CONSIDERED

49 percent of employment in India is dependent on agriculture, with 43 percent of India's geography dedicated to farming. The agriculture sector contributed approximately 17.5 percent of the country's GDP in 2015-2016 (Ahmad, Sinha, and Singh 2018). Given the varying soil and water conditions across the country, a variety of crops are cultivated across India. Crop production is divided into 4 distinct categories; the most prominent crops in India are cereal grains, which consist mainly of rice, wheat, maize, millets and pulses. The next are cash crops which include cotton, sugarcane, oilseeds, and tobacco. There are also plantation crops such as tea, coffee, and coconut as well as horticulture crops, which are fruits and vegetables ("Major Crops of India" n.d.).

Crops can be divided further based on the seasons in which they grow. In India, these are referred to as *Rabi*, *Kharif* and *Zaid*. *Kharif* crops are grown in summer during the monsoon season and consists mainly of millets (Bajra & Jowar), cotton, soybean, sugarcane, rice, and maize. *Rabi* crops consist of those grown in the spring or winter seasons and mainly refer to wheat, barley, sesame, mustard, and peas. *Zaid* crops are grown between March and June but only in certain parts of the country.

- **Rice:** India is one of the world's largest producers of rice; rice plays a vital role in India. It is not only a staple crop but also one that is important to the culture, religion, and economy. Nonetheless, rice is a very water intensive crop, requiring between 3,000 and 5,000 liters of water to produce one kilogram (Sharma, Prakriti 2017). Flood irrigation is necessary to grow rice in order to suppress weed growth and increase nutrient uptake in the soil.
- **Cotton:** India is the number one exporter of cotton yarn in the world. Cotton is highly water intensive, requiring 22,500 liters of water to produce one kilogram. Furthermore, cotton is typically grown in drier regions (Sharma, Prakriti 2017).
- **Sugarcane:** India is the 2nd largest producer of sugarcane after Brazil. It is a slow-growth crop meaning farmers rely on it for an annual income and without enough water, an entire sugarcane harvest can be destroyed. In the initial sugarcane growth phase 300-500 mm of rainfall is required. An additional 1,500-2,500 mm is needed to complete the growth cycle, thus bringing the overall water requirement to 1,500-3,000 mm to produce one kilogram of sugarcane (Sharma, Prakriti 2017).
- **Wheat:** Wheat is an extremely important crop in India due to its prevalence in Indian diets. Wheat production was greatly increased after the green revolution, and became the second most consumed crop in India after rice. India is currently the second largest wheat producer in the world. Wheat typically requires 900 liters of water to produce one kilogram. (Sharma, Prakriti 2017).

While switching to less water-intensive crops seems like an ideal solution, it is important to consider the importance of these crops in Indian culture. Moreover, potential alternative crops may not be well suited to the climate and soil conditions; therefore, in order to conserve water resources, adopting sustainable farming methods and improving irrigation techniques are essential.

Once UP was identified as the geographic focus area, the team looked into a recent study conducted in UP by the Department of Agricultural Economics at Banaras Hindu University. This study looked at the regional consumption of water to assess the water productivity of different crops grown throughout the state. They broke the state up into 4 distinct regions—Eastern, Central, Bundelkhand, and Western—as they noted that water availability differs considerably “from region to region as a result of rainfall, groundwater reserves and proximity to river basins” (Kumari, Singh, and Meena 2017). Moreover, there is a different combination of barriers and opportunities within each region and hence it is important to look at each region separately. For each crop analyzed, they examined the combination of blue (irrigation) and green water (rainfall) used per crop in each of the 4 regions.

Understanding the ‘crop per drop’ or the yields per unit of water used is an important benchmark to understand water efficiency and to “evaluate the sustainability and efficiency of agricultural water management.” In the study, they define this as crop-water productivity, which is measured as kilogram of crop produced from one cubic meter of water used or diverted ( $\text{kg}/\text{m}^3$ ). They compared seasons and found that most crops grown during the *Kharif* season use more green water whereas those grown during the *Rabi* and *Zaid* seasons require more irrigation. The information in this report is very detailed and does not pertain to the scope of our project however, we recommend a better understanding of the different regions of Uttar Pradesh and the consumptive use of water listed in detail (see

**Table 5-1.)** as well as the water productivity of each crop listed in **Table 5-2.** It is also worth mentioning that some of the crops with high water productivity such as lentils, potatoes, barley and maize can be considered for alternative crop options or are suitable for intercropping. Although sugarcane was noted as having the highest crop water requirement among the various cash crops, it was also found to have a comparative advantage in respect to crop yield and water productivity in the western region of the state. Policies should be framed around those crops which have a comparative advantage in particular region to maximize yield while minimizing water use (Kumari et al.).

Table 5-1. Region-wise Consumptive Water Use for Different Crops (m<sup>3</sup>/ha)

Crop	Eastern			Central			Bundelkhand			Western		
	Blue Water	Green Water	Total Water	Blue Water	Green Water	Total Water	Blue Water	Green Water	Total Water	Blue Water	Green Water	Total Water
Rice (K)	3389	5595	8985	3715	5207	8922	5316	3814	9130	3906	4862	8768
Rice (Z)	9603	1188	10791	10415	1045	11461	10135	1165	11300	9563	1036	10600
Maize (K)	1420	2907	4328	2189	600	2789	1987	2410	4397	1263	3242	4506
Maize (Z)	4967	2143	7110	5474	1804	7278	5204	2022	7226	5166	1552	6719
Jowar (K)	722	2949	3672	1125	2521	3646	1284	2434	3718	1164	2400	3565
Bajra (K)	722	2949	3672	1125	2521	3646	1284	2434	3718	1164	2400	3565
Small millets (K)	755	3025	3781	1156	2595	3751	1319	2505	3824	794	3008	3802
Arhar(K)	540	3269	3809	870	2895	3765	1015	2804	3819	2382	1760	4142
Urd (K)	540	3269	3809	870	2895	3765	1015	2804	3819	2382	1760	4142
Urd (Z)	5084	1114	6198	5501	886	6387	5231	1033	6264	4951	927	5878
Moong (K)	540	3269	3809	870	2895	3765	1015	2804	3819	2382	1760	4142
Moong (Z)	5084	1114	6198	5501	886	6387	5231	1033	6264	4951	927	5878
Moth (K)	540	3269	3809	870	2895	3765	1015	2804	3819	2382	1760	4142
Sesamum (K)	1517	3079	4596	1750	2936	4686	1939	2849	4788	2438	2668	5106
Groundnut (K)	1430	3196	4626	1856	2713	4570	2050	2631	4681	1585	3092	4677
Soybean (K)	1517	3079	4596	1750	2936	4686	1939	2849	4788	2438	2668	5106
Wheat (R)	6959	1176	8136	7256	1018	8275	7357	929	8286	6583	968	7551
Barley (R)	1847	532	2380	1841	537	2378	2041	415	2456	1793	425	2219
Gram (R)	1754	502	2256	1833	464	2297	2043	366	2409	1723	375	2098
Peas and beans (R)	1754	502	2256	1833	464	2297	2043	366	2409	1723	375	2098
Lentil (R)	1754	502	2256	1833	464	2297	2043	366	2409	1723	375	2098
Rapeseed-mustard (R)	5036	1814	6850	5489	1538	7027	5203	1751	6954	2736	2868	5605
Sunflower (Z)	5036	1814	6850	5489	1538	7027	5203	1751	6954	2736	2868	5605
Potato (R)	2297	636	2933	2426	577.5	3004	2737	461	3198	4274	1026	5300
Tobacco(R)	1897	532	2429	2024	464	2488	2247	366	2613	1908	370	2278
Sugarcane (K)	11278	4835	16113	12098	4352	16450	12247	6245	18492	10806	4694	15501
Cotton (K)	2395	4697	7092	2230	5225	7455	2183	5392	7575	3323	3564	6888

Note: K = kharif, R = Rabi and Z = zaid

Table 5-2. Region-wise Physical Water Productivity (kg/m<sup>3</sup>) for Different Crops

Crop	Eastern			Central			Bundelkhand			Western		
	Irr. Water (m <sup>3</sup> /ha)	Crop Yield (Kg/ha)	Water Productivity (Kg/M <sup>3</sup> )	Irr. Water (m <sup>3</sup> /ha)	Crop Yield (Kg/ha)	Water Productivity (Kg/M <sup>3</sup> )	Irr. Water (m <sup>3</sup> /ha)	Crop Yield (Kg/ha)	Water Productivity (Kg/M <sup>3</sup> )	Irr. Water (m <sup>3</sup> /ha)	Crop Yield (Kg/ha)	Water Productivity (Kg/M <sup>3</sup> )
Rice (K)	3390	2402	0.709	3715	2632	0.708	5316	1665	0.313	3906	2353	0.603
Maize (K)	1421	1379	0.971	2189	1874	0.856	1987	1351	0.680	1264	2113	1.672
Jowar(K)	723	961	1.329	1125	1120	0.996	1284	1015	0.790	1165	388	0.333
Bajra (K)	723	1264	1.749	1125	1404	1.248	1284	1022	0.796	1165	1488	1.278
Small Millets (K)	755	784	1.039	1156	544	0.471	1319	824	0.625	-	-	-
Arhar (K)	540	827	1.532	871	1019	1.171	1015	848	0.836	2383	962	0.404
Urd (K)	540	491	0.909	871	509	0.585	1015	372	0.367	2383	546	0.229
Moong (K)	540	237	0.438	871	374	0.430	1015	330	0.325	2383	236	0.099
Sesamum (K)	1430	150	0.105	1857	123	0.066	2050	125	0.061	1585	96	0.061
Groundnut(K)	1430	698	0.488	1857	812	0.437	2050	700	0.341	1585	548	0.346
Soybean(K)	1517	20	0.013	1750	926	0.529	1939	577	0.298	2438	570	0.234
Wheat (R)	6959	2902	0.417	7257	3468	0.478	7357	2124	0.289	6583	3721	0.565
Barley(R)	1848	2609	1.412	1841	2692	1.462	2041	2702	1.324	1794	3184	1.775
Gram (R)	1755	626	0.357	1833	545	0.297	2043	401	0.196	1724	516	0.299
Peas and beans (R)	1755	763	0.435	1833	1262	0.688	2043	867	0.424	1724	1278	0.742
Lentil (R)	1755	713	0.406	1833	701	0.382	2043	392	0.192	1724	1261	0.732
Rapeseed-mustard (R)	5036	753	0.149	5489	908	0.165	5203	360	0.069	2737	1294	0.473
Linseed (R)	5036	306	0.061	5489	478	0.087	5203	478	0.092	2737	409	0.150
Rice (Z)	9603	2405	0.250	10416	2550	0.245	-	-	-	9564	2407	0.252
Maize (Z)	4968	1804	0.363	5474	1837	0.336	-	-	-	5166	1847	0.357
Moong(Z)	5084	628	0.123	5502	564	0.103	5231	676	0.129	4951	543	0.110
Urd (Z)	5084	539	0.106	5502	607	0.110	-	-	-	4951	575	0.116
Sunflower (Z)	5036	150	0.030	5489	1612	0.294	5203	1568	0.301	2737	1536	0.561
Potato(R)	2298	17417	7.580	2427	18184	7.494	2737	21166	7.733	4275	21547	5.040
Tobacco(R)	1898	4884	2.574	2024	5105	2.522	2247	557	0.248	1908	2484	1.302
Sugarcane (K)	11278	59910	5.312	12098	59953	4.956	12247	42736	3.489	10807	63226	5.851
Cotton (K)	2395	214	0.089	2231	167	0.075	-	-	-	3324	234	0.070

Note: K = kharif, R = Rabi and Z = zaid

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## Appendix B.4. WATER EFFICIENT AGRICULTURAL TECHNOLOGIES

This section will review water efficient agricultural technologies that are relevant to the proposed business models, including drip irrigation, solar powered irrigation pumps, and intercropping.

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### Appendix B.4.1. IRRIGATION TECHNOLOGIES

There are three main agricultural irrigation practices: surface irrigation (also known as flood irrigation), sprinkler irrigation, and drip irrigation (also known as micro-irrigation).

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#### APPENDIX B.4.1.1. SURFACE IRRIGATION

Surface irrigation, the most common irrigation type in India, is the simplest form of irrigation, consisting of flooding the cropland's ground surface which allows gravity to distribute water through strategically designed dikes or small channels. Implementing a surface irrigation system requires little initial capital or maintenance cost because it does not use any mechanical equipment. Surface irrigation systems that use water pumps typically have low energy requirements. Also, surface irrigation can be used with most soil types and different crops. The inherent nature of water being distributed at the surface level reduces the risk of crops acquiring disease as surface water doesn't wet plant foliage or hanging fruit. (Evans, n.d.)

On the other hand, properly preparing cropland for surface irrigation can be challenging since the slope of the land must be less than 3 percent. Also, it is important to consider the characteristics of the soil, such as its porosity, as this impacts distribution of the water across the surface area. Surface irrigation has low water efficiency compared to the other methods because the water is applied over the whole surface area as opposed to directly on the plant, meaning a portion of it will be lost to the soil and evapotranspiration. (Evans, n.d.)

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#### APPENDIX B.4.1.2. SPRINKLER IRRIGATION

Sprinkler irrigation transports water through pressurized tubes and eventually administers water onto the crops through the air. There are different types of sprinkler irrigation systems, ranging from automated electric systems to hand-powered systems commonly used in cheaper labor markets. Like surface irrigation systems, sprinkler systems can be used for different soil types and crops. The main relative advantage, though, is that sprinkler irrigation is significantly more water efficient than surface irrigation and can be used across fields with irregular topographies. Moreover, fertilizers and agricultural chemicals can be administered through the water sprinklers (Evans, n.d.).

Unfortunately, the high, upfront, capital and maintenance costs of sprinkler irrigation can be a barrier for many farmers. The equipment required, including filters, pressure regulators, and different sensors, can be very sophisticated and expensive. Sprinkler irrigation also consumes significant quantities of energy. Last, the speed and size of the water droplets can cause damage to the crops (Evans, n.d.).



Drip irrigation, also called micro-irrigation or trickle irrigation, is a water efficient technology that provides water directly to the plant root zone slowly and frequently (usually every two or three days, depending on the crop type). Drip irrigation application may reach a water efficiency level of above 90 percent, while surface irrigation ranges from 45 to 85 percent depending on the method used. Sprinkler irrigation is approximately 60 to 80 percent efficient (Evans, n.d.).

Drip irrigation consists of a low-cost water delivery system, which is generally made up of five major components: valves, filters, pressure regulators, pipes, and a blowout valve or automatic drain. This design applies water directly to the soil in specific locations, at a low pressure and flow rate, resulting in a soil surface that is not wet, producing minimal waste from drift, evaporation or runoff. This low surface evaporation is a common issue that results in low water efficiency in current Indian irrigation practices (especially in flood irrigation) (Evans, n.d.).

Drip irrigation systems are advantageous due to their ease of assembly, installation, connection to the existing main water line, and modification which allows them to be adapted to almost any cropping situation and climatic zone. These systems are also able to be used over a wide range of terrain conditions, in different type of soils (either very low or very high infiltration rates), and with poorer water quality than could be used with other irrigation systems. Due to these factors, drip irrigation technology is increasing in popularity. Still, it is crucial to understand the soil characteristics, topography of the landscape, and the crops' water needs in order to have a successful system implementation (Cox and Mills, n.d.).

Other advantages of drip irrigation systems include (Cox and Mills, n.d.):

- Lower price of installation as compared to other systems.
- If pumps are required, their energy costs are typically lower compared to other irrigation technologies that also use pumps.
- Lower chance of disease in plants due to less excess water on foliage.
- Higher safety potential due to more efficient application of fertilizers.
- Low Irrigation labor costs

As with any technology, drip irrigation has some disadvantages, the most significant of which is the required maintenance. Firstly, the orifices of the pipes are susceptible to plugging due to their small size, making it necessary to filter and treat the water before being run through the system in order to remove any sediment, algae, bacteria and other debris. Moreover, frequent maintenance checks are required to prevent and detect rodent damage, mechanical damage, or any deterioration of the plastic components when exposed to arid and hot climates due to ultraviolet light (Cox and Mills, n.d.; Evans, n.d.).

To summarize, drip irrigation systems may have considerable advantages against other technologies particularly in terms of water efficiency. However, these concerns should be weighed against the potentially low life span and maintenance costs of systems due to environmental exposure.

India primarily runs on coal, with solar energy constituting only one percent of the country's energy mix. However, the government has ambitious plans to change this by increasing solar production. With approximately 300 sunny days per year in many parts of the country, India is well suited for solar energy. The Indian government has set an ambitious energy target of 100,000 megawatts of solar power by 2020 which would mean 10 percent of the total energy mix would be derived from the sun (Ross and Gerholdt 2017). Most of the solar projects the government is sponsoring are large-scale, but two organizations, the International Water Management Institute (IWMI) and CCAFS (CGIAR's research program on Climate Change, Agriculture and Food Security), have identified solar power as a remunerative "cash crop" for farmers. In this scheme, known as Solar Power as a Remunerative Crop (SPaRC), farmers will obtain solar-powered irrigation pumps to replace the diesel or electric ones currently in use. This program would not only cut emissions from the farm sector by six percent but would also incentivize farmers to generate solar energy on their farms which could then potentially be sold back to the electricity grid and provide an additional revenue source (Shah and Parthasarathy 2015).

Currently, there are approximately 30 million irrigation pumps installed throughout India. Of those, about 30 percent are powered by diesel, 70 percent are powered by the grid, and the remaining 0.4 percent are solar powered (Raymond and Jain 2018). Given that sugarcane farmers in India are highly dependent on irrigation and the Indian government has set ambitious goals to add renewable energy into their mix, the increase in availability and use of solar pumps is essential. Today, many Indian states in coordination with the Ministry of New and Renewable Energy (MNRE) offer a solar pump subsidy which covers as much as 90 percent of the overall costs. MNRE has an ambitious target to provide one million solar pumps by the year 2021 (S. Agrawal and Jain 2018).

Access to irrigation is one of the biggest hurdles facing small and marginal farmers yet the availability of irrigation is necessary to enhance productivity and bring in greater incomes. A survey done of 1,600 farmers in UP showed that about half of them rented or purchased water from larger farm holders and only 41 percent of those surveyed with less than a hectare of land owned their own borewell to extract groundwater. Solar pumps "hold the potential to enhance irrigation access, advance low-carbon agriculture, reduce the burden of electricity subsidies by the government, and improve the resilience of farmers against a changing climate" (Bera 2018a).

A major concern with solar pumps is that the "availability of a steady and (almost) free supply of power risks the overuse of pumps" which would negate some of the positive aspects of this subsidy as aquifers are already stretched to capacity and groundwater is depleting at an alarming rate (Shah and Parthasarathy 2015). The overuse of irrigation pumps has already been a concern in India, as electricity is fully subsidized by the Central Government for farmers. The sporadic nature of grid energy encourages farmers to run these pumps continuously in order to avoid manual intervention each time the power becomes available. To make the solar power subsidy work in favor of water efficiency, the government will have to incorporate water savings incentives, prevent the overexploitation of

groundwater through selective pumping, promote clean energy sources, and phase out part of the subsidized electricity (Shah and Parthasarathy 2015).

A study published in 2018 by the Council on Energy, Environment, and Water (CEEW), a prominent South Asian policy research institute, identified a number of issues presented with this model. They note that even though 130,000 Solar Powered Irrigation Systems (SPIS) have been installed in the last 5 years (Raymond and Jain 2018), making India the world's largest solar pump market, "a subsidy-led approach would be fiscally unviable to achieve deployment of SPIS at scale, given the high upfront cost" (S. Agrawal and Jain 2018). Moreover, if SPIS were to be scaled up without addressing the need for water management, especially in water-stressed regions of the country, the problem would persist. They recommend that financial support should link incentives for solar pump technology with those for groundwater management and efficient irrigation practices. These experts contend that only by combining solar pump subsidies with water conservation measures will the problem be adequately addressed (S. Agrawal and Jain 2018).

Another concern is the barrier of the high upfront cost of solar pumps present to small farmers. While 10 percent of the costs does not sound like much, this subsidy would still rely heavily on the availability of financing as credit for farmers would still be necessary (S. Agrawal and Jain 2018). These financing sources are not readily available, as most are provided by farmer cooperatives with steep competition for funding between small farmers (**See 3.2.1.3 "Cooperative Societies"**). However, the operating costs over the lifetime of the solar pump is less than that of a diesel pump, meaning costs could be offset (Raymond and Jain 2018).

CEEW conducted another study, also in 2018, using an economic model to compare the cost advantages of farmers owning and operating diesel pumps versus solar alternatives. CEEW notes that while solar pumps have a higher upfront cost than diesel pumps, the lifetime cost of solar pumps will offer savings to farmers given their low operating expenses compared to that of diesel ones. The study looks at different economic approaches to promoting solar pumps; in each approach, experts consider the farmer and government perspectives based on energy efficiency, water management practices, and financial benefits. One of the key findings, which also support our team's research, is that models that include "'Water-as-a-service' by village level entrepreneurs, including farmers with surplus pumping energy, is a promising model for improving the utilization of solar pumps creating additional revenue, thus improving their economic viability and providing irrigation access to marginal farmers" (Raymond and Jain 2018).

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#### Appendix B.4.2. INTERCROPPING CROP SELECTION

Intercropping is the practice of growing two or more crops on the same piece of land with defining row patterns in order to produce a higher yield per unit area over the same amount of time. It is a long-standing tradition that has been practiced for thousands of years. Nevertheless, current research and development in this field is less advanced than that for monoculture methods and therefore, intercropping appears to be declining in popularity. In March 2017, the central government announced a policy to double farmers income by 2022 through resource use efficiency, improvements in

productivity, and diversification towards high value crops. Intercropping is one method to help achieve this target goal and sugarcane farmers should be encouraged to adopt intercropping and grow pulses, oilseeds or vegetables alongside their sugarcane (S. N. Singh et al. 2018) (Kaundinya n.d.).

Sugarcane is a long-duration, slow-growth crop that is very suitable for intercropping with cereals, legumes, oilseeds and fiber crops. Due to slow establishment of sugarcane during the first 90-120 days [of cultivation], the greatest scope for complementary effect lies in the addition of annual intercrops to the temporal season to improve resource use efficiency in the early crop growth (S. N. Singh et al. 2018). The subtropical states encompass 57.1 percent of the total cane area, of which Uttar Pradesh is the main cane growing state with about 2.2 million hectares under cultivation (S. N. Singh et al. 2018). In the subtropical region, sugarcane is planted in the autumn season and hence, successful intercropping can be achieved with *Rabi* crop. Typical row planting is done with a 90cm separation; although in order for intercropping to be successful with sugarcane, wider row spacing, preferably 150 cm is ideal. A 2012 study states that “Such wider row spacing permits intercropping without adversely affecting the cane yield and thus increasing the overall productivity and profitability of the system” (Gopalasundaram, Bhaskaran, and Rakkiyappan 2012). Intercropping is successful so long as it provides additional income and increases total productivity without sacrificing cane yield.

Farmers in UP plant sugarcane between May and June and the first harvest is around mid-November to Early December. The sugarcane crop completes its germination in approximately 5 weeks and canopy closure around the 15th week after planting. Therefore, the chosen intercrop should be a dwarf type plant with a short duration such as a legume, oilseed, or a vegetable. Soybean intercropping has been shown to positively influence cane yield; when soybean is mixed with sun hemp and cowpea, the additives act like green manures that can improve the soil chemical properties and act like nitrogen fertilizers.

The use of leguminous intercrops can help increase nitrogen levels in the soil, enhancing soil fertility, and avoiding the need for inorganic fertilizers. This happens through the excretion of amino acids into the rhizosphere, the portion of the soil found adjacent to the roots of the plant. This is the part of the soil where nutrients are exchanged and the nitrogen-fixed by the legumes can be taken up by the intermediary crop as well as the sugarcane where it will remain available for the duration of the growing season. Soil health can also be improved through the addition of crop residues after the intermediary crop is harvested. Inorganic fertilizers are known to cause environmental damage such as nitrate pollution, lowering the applications of these chemicals presents a more sustainable, environmentally-friendly option. Therefore, intercropping can produce higher yields while also improving the soil health.

Because of its long duration period, sugarcane is often referred to in India as the “lazy man’s crop.” This is because there is not much labor demand during the growth period, providing a great opportunity to raise a *Rabi* crop as an intercrop with autumn-planted sugarcane. Moreover, as the demand for vegetables are on the rise, intercropping presents a market opportunity for smallholder farmers to increase their yields and hence their financial returns (S. N. Singh et al. 2018). **Table 5-3** provides Singh’s results on yields and potential economic returns.

Table 5-3. Effect of Vegetables Intercropping in Sugarcane Growth, Yield Potentials, and Economic Returns

Treatments	No. of tillers ('000/ha)	No. of millable canes ('000/ha)	Yield of intercrops (q/ha)	Yield of cane (tonne/ha)	CCS (%) cane	Cane equivalent yield (tonne/ha)	% decrease in cane yield over sole cane	% increase in cane equivalent over sole cane	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio
Autumn cane sole	315	134	-	94.50	10.20	94.50	-	-	121,715	133,395	1.10
Cane + cauliflower	253	129	201.20	90.69	10.14	137.10	4.03	45.08	143,623	226,547	1.58
Cane+cabbage	254	126	225.40	91.20	10.12	141.15	3.49	49.37	143,715	237,525	1.65
Cane+knol-khol	257	122	245.20	90.50	10.31	139.54	4.42	47.66	143,709	232,941	1.62
Cane+turnip	248	121	280.00	90.01	10.41	129.78	4.75	37.33	145,634	204,826	1.41
Cane+carrot	215	111	182.50	85.15	10.60	123.81	9.89	3.50	145,579	188,681	1.30
Cane+radish	229	113	305.00	83.60	10.44	113.06	11.53	19.64	143,810	161,560	1.12
Cane+potato	341	139	245.05	102.30	10.29	179.44	(+)8.25	89.88	163,098	321,282	1.97

CCS: Commercial Cane Sugar, Cost of cultivation given is as per economics calculated in 2014-15, B:C – Benefit Cost ratio

There is much promise for intercropping with sugarcane, but more research is needed to better understand and develop successful intercropping systems that are compatible with current sugarcane farming methods. Most notably, flood irrigation does not work well for many *Rabi* vegetables and hence, sprinkler, drip, or micro irrigation methods must be employed for intercropping to be successful. While this research is still in its nascent phases, it is clear that the government supports the adoption of intercropping with sugarcane. It is recommended that more research and development should go into better understanding the benefits and potentials of intercropping (S. N. Singh et al. 2018).



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## Appendix B.5. MARKET RESEARCH

This section will review market research relevant for the proposed business models, including background research on Indian agricultural markets, cooperative societies and agricultural subsidies. All of these components will play an important part in the business models, making these topics crucial to understand when considering implementation of any of the three proposals.

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### Appendix B.5.1. AGRICULTURAL MARKETS

Agricultural markets for cash crops in India are primarily controlled at the local level by state governments. Although the central government has no control on agricultural markets, the typical structure of the state markets is consistent from state to state, with all states—except four—choosing to adopt an Agricultural Produce Marketing Committee (APMC).

The APMC is given control of statewide agricultural sales. The primary objective of each APMC is to ensure that farmers are not exploited by intermediaries and to reduce inefficiencies in the market due to multiple points of sale. Both UP and Uttarakhand are states with APMCs in charge of statewide agricultural sales (S. N. Singh et al. 2018).

Each state's APMC is in charge of establishing and overseeing local agricultural markets, or *mandis*, where farmers can sell their produce, which can then be sold to large buyers. APMC regulation requires farmers to sell their crops only to licensed mandis; neither intermediary markets nor sales direct to the consumer are permitted (P. Sharma 2017).

One challenge that farmers face due to the *mandi* system is the need to rely on middlemen called village aggregators who gather produce from several smaller farmers to bring to market. This issue particularly impacts smaller farmers and farmers located in remote regions without reliable access to transportation leading to their inability to bring their produce to the *mandis* directly. The introduction of an intermediary creates an unforeseen challenge to the *mandi* system. Village aggregators charge a transaction fee on each end of the sale, leaving farmers with as little as 25 percent of the ultimate sale price (P. Sharma 2017).

In addition to the transaction fees charged by the middlemen, farmers are also victims of price gouging due to the lack of availability of up-to-date pricing information, as prices for crops at the *mandis* vary on a daily basis. Farmers who are selling to the middlemen rather than taking their crops directly to the *mandi* do not know what the current price of their produce is, putting the small, rural farmers at an even greater disadvantage (P. Sharma 2017).

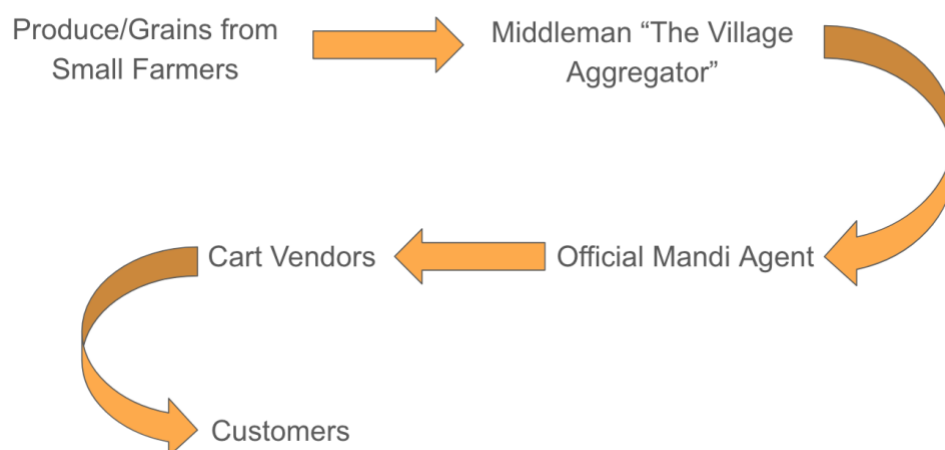


Figure 5-A. The Flow of Agricultural Goods from Small Farmers to Customers

Although the original intent during the creation of the statewide APMCs was to reduce inefficiencies, the current *mandi* system in India remains highly inefficient. The use of village aggregators has increased transaction costs without rewarding farmers with any increased profit. Inadequate infrastructure at small farms and *mandis*, most notably the lack of refrigeration and cold storage, make food spoilage a serious concern for farmers. Given this risk of spoilage, farmers may not have the privilege to wait for a better price, choosing to accept a lower price rather than to operate at a complete loss in the event that their produce spoils prior to sale at a higher price.

#### APPENDIX B.5.1.1. PUBLIC DISTRIBUTION SYSTEM (PDS)

The ambiguity in pricing of cash crops and the difficulties of selling them to the state *mandi* system has incentivized smaller farmers to participate in India's other agricultural market: the public distribution system (PDS). The PDS market, created by the Indian federal government in 1940s, was introduced to help provide sufficient wartime rations to India's citizens. The PDS system was revamped in 1997 as a social service program to help feed India's poor and at-risk populations. Families deemed to be below the poverty line are entitled to a ration card, which allows them to receive food grains, sugar, and oil from PDS outposts (M. Singh 2005).

Under the PDS system, the Indian central government agrees to purchase all PDS food grains from farmers, regardless of actual demand or need, at a predetermined fixed price known as the minimum support price (MSP). In UP, the PDS food grains are wheat, rice, and sugar. This certainty in price allows farmers to better plan their future cash flows unlike in the *mandis* system discussed earlier (Balani 2013).

In addition to alleviating farmers' concerns over future cash flows, the PDS system helps farmers address issues with regards to crop transportation and storage, as the federal government has an established system to collect and store procured PDS crops in each state.

## Appendix C. KEY TERMINOLOGY & DEFINITIONS

The following terms occur throughout the report; their definitions are noted below:

**Alliance for Water Stewardship (AWS):** is a global membership comprising of businesses, non-profit organizations, and members of the public sector who are dedicated to water conservation and stewardship.

**bagasse:** the residue left after extracting the juice from the sugarcane that can be used as fuel to generate electricity.

**CGIAR:** a global research partnership addressing food security and dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources.

**Climate Change, Agriculture and Food Security (CCAFS):** a collaboration among all 15 CGIAR Research Centers addressing issues regarding climate change and food security.

**Consumer Packaged Goods (CPG):** items that are sold quickly at a relatively low cost and need to be replaced regularly.

**cooperative society or cooperative (“Co-op”):** An association or corporation established for the purpose of providing services on a nonprofit basis to its shareholders or members.

**Corporate social responsibility (CSR):** is when a mid to large cap company uses a percentage of their profits to give back to the community at large through actions that seek to provide good either socially, environmentally, or otherwise.

**Cropping intensity:** refers to one or more crops grown on the same field during one agriculture year. It can be expressed as  $Cropping\ intensity = (Gross\ cropped\ area / Net\ sown\ area) \times 100$ , where the Gross cropped area is the total potential land to be cultivated and Net sown area is the actual land used.

**crore:** common Indian unit of measure equating to ten million, or one hundred lakhs.

**DISCOM:** the abbreviation referring to the local power distribution company in India.

**Drip irrigation (or ‘micro-irrigation’):** A common irrigation method involving controlled uniform delivery of water and fertilizer to the root area of the plant.

**Electricity offtaker or Offtaker:** An offtaker agreement is one in which the offtaker agrees to purchase a resource from the other entity in the agreement at a future time. For the purpose of this report, an electricity offtaker is the entity agreeing to purchase the electricity that will be generated.

**Fair and Remunerative Price (FRP):** The minimum price at which sugarcane farmers can sell their produce. This price is regulated by the central government.

**Ganges (or ‘Ganga’) River:** A transboundary river in the plains of the northern indian subcontinent.

**Genetic Engineering Appraisal Committee (GEAC):** An entity in India responsible for regulating the manufacturing, usage, import, export and storage of hazardous microorganisms or genetically engineered organisms or cells.

**genetically modified (GM):** The process of changing the structure of the genes of a living thing in order to produce a desired characteristic.

**Greenhouse gas (GHG):** any of various gaseous compounds (such as carbon dioxide or methane) that absorb infrared radiation, trap heat in the atmosphere, and contribute to the greenhouse effect.

**Gross Cropped Area (GCA):** See **Cropping intensity**

**Gross Domestic Product (GDP):** the total value of goods produced and services provided in a country during one year.

**gur (or 'jaggery'):** is made from unrefined sugar, and is obtained by boiling raw, concentrated sugar cane juice till it solidifies.

**hectare:** a metric unit to measure land or area equivalent to 10,000 square meters or 2.5 acres.

**Indian Council of Agricultural Research (ICAR):** an autonomous body responsible for coordinating agricultural education and research in India.

**Indian Institute of Sugarcane Research (IISR):** a unit under Government of India dedicated for conducting research on fundamental and applied aspects of sugarcane.

**intercropping:** growing two or more crops on the same piece of land to increase productivity per unit of farm area over the same period of time.

**Intergovernmental Panel on Climate Change (IPCC):** is an intergovernmental body of the United Nations, dedicated to providing the world with an objective, scientific view of climate change and its political and economic.

**International Water Management Institute (IWMI):** is a non profit research institute focused on development to deliver new evidence-based approaches that address key water-related challenges

**ISEAL Alliance:** is the global membership association for credible sustainability standards.

**khandsari** (or 'muscovado'): a partly refined sugar

**Kharif:** autumn crops; sown in autumn and harvested in the summer season

**kWp (kilowattpeak):** is a measurement used to compare the performance of PV systems and depends on location, orientation, and various other factors. 1 kWp=1000 Wp (watt-peak) with a watt-peak being the total potential electric power that can be supplied by one PV panel in standard conditions.

**lakh:** an Indian unit of measurement equating to one hundred thousand

**mandi:** a local agricultural market where farmers sell their produce in India.

**marginal farmer:** a farmer cultivating a plot of land up to one hectare (2.5 acres).

**“Meetha Sona Unnati”:** a project initiated by Coca Cola partnering with DCM Shriram, Solidaridad and International Finance Corporation to enhance sugarcane yield and improve farmers’ income in Uttar Pradesh.

**Microgrid:** a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.

**Minimum support price (MSP):** the price at which government purchases crops for the farmers, to safeguard the interests of the farmers.

**Net Sown Area:** see **Cropping intensity**

**perennial river:** a river that has continuous flow throughout the entire year except in periods of extreme drought. Non-perennial rivers, on the other hand, have no flow for part of the year. In India almost all perennial rivers, including the Ganges River, originate from the Himalayan range.

**Photovoltaic system (PV):** a power system designed to supply solar power by means of photovoltaics.

**Power-Purchase Agreement (PPA):** a legal contract between an electricity generator (provider) and a power purchaser (electricity buyer).

**Public Distribution System (PDS):** a Central Government program that facilitates the supply of food grains and distribution of essential commodities to a large number of poor people through a network of Fair Price Shops at a subsidized price on a recurring basis.

**Rabi:** Winter crops; sown in winter and harvested in the spring season.

**Salinization:** An overabundance of salt in the soil which makes absorption by plants difficult and is usually caused by over irrigating agricultural lands and often accompanies waterlogging (see **Waterlogging**).

**smallholder farmer:** a farmer cultivating a plot of land that is more than 1 hectare (2.5 acres) yet less than 2 hectares (5 acres).

**Solar Power as a Remunerative Crop (SPaRC):** Indian project that promotes solar power generation by smallholder farmers as a source of additional income.

**Solar-powered irrigation system (SPI):** is a complete system which provides fresh water from a well and reservoir for use in livestock, domestic use and industrial or agriculture by using solar power.

**Sprinkler irrigation:** is a method of applying irrigation water using sprinkler technology.



**State Advised Price (SAP):** A locally mandated price for sugarcane set by the state government and often substantially higher (30-35%) than the Fair and Remunerative Price (FRP).

**Strengths/Weaknesses/Opportunities/Threats (SWOT):** A framework to help organizations identify strengths, weaknesses, opportunities, and threats related to a project.

**Subtropical Indian States:** States in India bordering the equator.

**Surface (or 'flood') irrigation:** is where water is distributed over the soil surface by gravity.

**Tropical Indian States:** States in India which are located within the regions either 10 degrees north or 10 degrees south of the equator.

**Uttar Pradesh Power Corporation Ltd (UPPCL):** company responsible for electricity transmission and distribution in UP

**Vasantdada Sugar Institute (VSI):** established in 1975 by the sugarcane growers of the co-operative sugar factories. The institute performs scientific, technical, and educational functions relevant to the Sugar Industry.

**Waterlogging:** the saturation of water in soil which negatively affects air flow and is often associated with soil salinity. The two combined can decrease agricultural productivity.

**World Resource Institute (WRI):** a global research institute that spans 60 countries and has over 700 experts and staff. Their research influences movements toward a cleaner environment, improved human welfare, and economic opportunities.

**Zaid:** spring crop; sown in spring and harvested in the summer season.

## Appendix D. BIBLIOGRAPHY

- Agarwal, Vibhuti. 2016. "Farm Subsidies Put India in Bind." *Wall Street Journal*, May 1, 2016, sec. Markets. <https://www.wsj.com/articles/farm-subsidies-put-india-in-bind-1462121185>.
- Aggarwal, P.K. 2008. "Global Climate Change and Indian Agriculture: Impacts, Adaptation, and Mitigation." *Indian Journal of Agricultural Sciences* 78 (10): 911–19. <http://www.indiaenvironmentportal.org.in/files/Global%20Climate%20Change.pdf>.
- Agrawal, Arunabha Ghosh & Shalu. 2015. "Arunabha Ghosh & Shalu Agrawal: Sustainable Solar Irrigation." *Business Standard India*, August 17, 2015. [https://www.business-standard.com/article/opinion/arunabha-ghosh-shalu-agrawal-sustainable-solar-irrigation-115081701282\\_1.html](https://www.business-standard.com/article/opinion/arunabha-ghosh-shalu-agrawal-sustainable-solar-irrigation-115081701282_1.html).
- Agrawal, Shalu, and Abhishek Jain. 2018. "Financing Solar for Irrigation in India." Council on Energy, Environment and Water. <https://www.ceew.in/publications/financing-solar-irrigation-india>.
- "Agricultural Statistics at a Glance." 2017. Government of India Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare Directorate of Economics and Statistics.
- Ahmad, Nasim, D.K.Sinha Sinha, and K Singh. 2018. "Economic Analysis of Growth, Instability and Resource Use Efficiency of Sugarcane Cultivation in India: An Econometric Approach," April.
- "Annual Report 2017-18." 2018. New Delhi: Department of Agriculture, Cooperation & Farmers Welfare. <http://agricoop.nic.in/sites/default/files/Krishi%20AR%202017-18-1%20for%20web.pdf>.
- Aradhey, Amit. 2018. "India Sugar Semi-Annual 2018." Global Agriculture Information Network IN8115. USDA Foreign Agriculture Service.
- Badiani, Reena, and Katrina K Jessoe. 2011. "Electricity Subsidies for Agriculture: Evaluating the Impact and Persistence of These Subsidies in India DRAFT." ResearchGate. October 2011. [https://www.researchgate.net/publication/228431827\\_Electricity\\_subsidies\\_for\\_agriculture\\_Evaluating\\_the\\_impact\\_and\\_persistence\\_of\\_these\\_subsidies\\_in\\_India\\_DRAFT](https://www.researchgate.net/publication/228431827_Electricity_subsidies_for_agriculture_Evaluating_the_impact_and_persistence_of_these_subsidies_in_India_DRAFT).
- Balani, Sakshi. 2013. "Functioning of the Public Distribution System." *PRS Legislative Research*, December, 22.
- Balch, Oliver. 2016. "Indian Law Requires Companies to Give 2% of Profits to Charity. Is It Working?" *The Guardian*, April 5, 2016, sec. Guardian Sustainable Business. <https://www.theguardian.com/sustainable-business/2016/apr/05/india-csr-law-requires-companies-profits-to-charity-is-it-working>.
- Baron, Jill S, and N LeRoy Poff. 2004. "Sustaining Healthy Freshwater Ecosystems." *Universities Council on Water Resources*, Water Resources Update, , no. 127 (February): 52–58.
- Bera, Sayantan. 2018a. "60% of Marginal Farmers in Uttar Pradesh Purchase Water for Irrigation, Finds Study." <https://www.livemint.com/>. January 18, 2018. <https://www.livemint.com/Politics/yYi59vNfIHgO4wcXF2GEnI/60-of-marginal-farmers-in-Uttar-Pradesh-purchase-water-for.html>.

- . 2018b. "Small and Marginal Farmers Own Just 47.3% of Crop Area, Shows Farm Census." <https://www.livemint.com/Politics/k90ox8AsPMdyPDuykv1eWL/Small-and-marginal-farmers-own-just-473-of-crop-area-show.html>. October 1, 2018.
- Cartwright, Mark. 2015. "Ganges." *Ancient History Encyclopedia*. Ancient History Encyclopedia. <https://www.ancient.eu/Ganges/>.
- Census of India 2011. n.d. "Population Density (Per Sq. Km.)." NITI Aayog. Accessed December 12, 2018. <http://niti.gov.in/content/population-density-sq-km>.
- Central Water Commission, S.K. Madaan, and S.R. Meena. 2017. "Pricing of Water in Public System in India 2017." New Delhi: Central Water Commission. <http://www.indiaenvironmentportal.org.in/files/file/Pricing%20of%20Water%20in%20Public%20System%20in%20India%202017.pdf>.
- Cornish, G, B Bosworth, C Perry, and J Burke. 2004. "Water Charging in Irrigated Agriculture - An Analysis of International Experience." Rome: Food & Agriculture Organization. <http://www.fao.org/docrep/008/y5690e/y5690e00.htm#Contents>.
- Cox, David M., and Linn Mills. n.d. "Drip Irrigation Systems." University of Nevada.
- Department of Agriculture & Cooperation Mechanisation & Technology Division. n.d. "UP." GOVERNMENT OF INDIA Ministry of Agriculture. Accessed November 24, 2018a. <https://farmech.dac.gov.in/FarmerGuide/UP/index1.html>.
- . n.d. "Uttarakhand." GOVERNMENT OF INDIA Ministry of Agriculture. Accessed November 24, 2018b. <https://farmech.dac.gov.in/FarmerGuide/UK/Introduction.htm>.
- Department of Environment. 2014. "Uttar Pradesh State Action Plan on Climate Change." Government of Uttar Pradesh. [http://www.moef.gov.in/sites/default/files/SAPCC\\_UP\\_final\\_version\\_0.pdf](http://www.moef.gov.in/sites/default/files/SAPCC_UP_final_version_0.pdf).
- Dhawan, Vibha. 2017. "Water and Agriculture in India: Background Paper for the South Asia Expert Panel during the Global Forum for Food and Agriculture (GFFA) 2017." The Energy and Resources Institute (TERI).
- DTE Staff. 2018. "688 Billion Cubic Metres: India's Water Withdrawals for Agriculture Is the Highest in the World." June 28, 2018. <https://www.downtoearth.org.in/news/water/688-billion-cubic-metres-india-s-water-withdrawals-for-agriculture-is-the-highest-in-the-world-60967ref=true>.
- Eaton, Charles, and Andrew Shepherd. 2001. "Contract Farming. Partnerships for Growth." FAO Agricultural Services Bulletin 145. Rome: FAO. <http://www.fao.org/docrep/014/y0937e/y0937e00.pdf>.
- "Environmental Aspects Tehri Dam." n.d. Engineering. Accessed December 3, 2018. <https://www.slideshare.net/ektapatel40/environmental-aspects-tehri-dam-final>.
- Evans, Robert G. n.d. "Irrigation Technologies." USDA Agricultural Research Service. <https://www.ars.usda.gov/ARSUserFiles/30320500/IrrigationInfo/general%20irrigation%20systems-mondak.pdf>.

- Food and Agriculture Organisation. 2010. "Water-Efficient Sugarcane Farming in Belgaum, Karnataka." Text. India Water Portal. February 17, 2010. <http://www.indiawaterportal.org/articles/water-efficient-sugarcane-farming-belgaum-karnataka>.
- Gibb, Christine, Reuben Sessa, Youth and United Nations Global Alliance, and Food and Agriculture Organization of the United Nations, eds. 2013. *The Youth Guide to Biodiversity*. 1st edition. Youth and United Nations Global Alliance Learning and Action Series. Rome: Food and Agriculture Organization of the United Nations.
- Gopalasundaram, P, A Bhaskaran, and P Rakkiyappan. 2012. "Integrated Nutrient Management in Sugarcane." *Sugar Tech* 14 (1): 3–20.  
[https://www.researchgate.net/publication/257780383\\_Integrated\\_Nutrient\\_Management\\_in\\_Sugarcane](https://www.researchgate.net/publication/257780383_Integrated_Nutrient_Management_in_Sugarcane).
- Goswami, Shreya. 2017. "Here's Why Sugarcane Is Worshipped on Devotthan or Prabodhini Ekadashi - Lifestyle News." India Today. October 31, 2017.  
<https://www.indiatoday.in/lifestyle/culture/story/sugarcane-devotthan-prabodhini-ekadashi-ganne-ki-puja-worship-hindu-festival-indian-farmers-lifest-1078818-2017-10-31>.
- Government of India. 2011. "Uttar Pradesh Administrative Divisions 2011." Census 2011.
- . 2017. "Report of the Committee on Doubling Farmers' Income "Status of Farmers' Income: Strategies for Accelerated Growth" Inter-Linkages between Input Costs, Diversification, Capital Formation and Income." Volume II.
- . 2018a. "Agriculture Census for 2015-16." Agriculture Census Division Department of Agriculture, Co-Operation & Farmers Welfare Ministry Of Agriculture & Farmers Welfare Government Of India.
- . 2018b. "Department of Agriculture Cooperation & Farmers Welfare Annual Report." Department of Agriculture Cooperation & Farmers Welfare | Mo A&FW | GoI. 2018.  
<http://agricoop.nic.in/annual-report>.
- Guruswamy, Mohan. 2017. "Food for Thought: India Will Have 1.7 Billion People by 2050. How Will It Feed Them All?" Text. Scroll.In. May 29, 2017. <https://scroll.in/article/838970/food-for-thought-india-will-have-1-7-billion-people-by-2050-how-will-it-feed-them-all>.
- Hiloidhari, M, M. Araújo, and S Kumari. 2018. "Bioelectricity from Sugarcane Bagasse Co-Generation in India—An Assessment of Resource Potential, Policies and Market Mobilization Opportunities for the Case of Uttar Pradesh.," no. 182.
- IANS. n.d. "Farmers to Pay Only 10% Cost of Solar Pumps under Budget Scheme: Minister." ETEnergyworld.Com. Accessed December 3, 2018.  
<https://energy.economictimes.indiatimes.com/news/power/farmers-to-pay-only-10-cost-of-solar-pumps-under-budget-scheme-minister/62765093>.
- India Brand Equity Foundation. 2018a. "About Uttar Pradesh: Tourism, Agriculture, Industries, Economy & Geography." October 2018. <https://www.ibef.org/states/uttar-pradesh.aspx>.
- . 2018b. "Industrial Development & Economic Growth in Uttarakhand." November 2018.  
<https://www.ibef.org/states/uttarakhand-presentation>.

- Indian Council of Agricultural Research. n.d. "Uttar Pradesh." Ministry of Agriculture and Farmers Welfare. Accessed December 3, 2018. <https://icar.org.in/files/state-specific/chapter/119.htm>.
- "Information on Canals of Uttar Pradesh That Helps in Irrigation." n.d. Accessed November 14, 2018. <http://www.preservearticles.com/2012020422791/information-on-canals-of-uttar-pradesh-that-helps-in-irrigation.html>.
- Jain, Abhishek, and Tauseef Shahidi. 2018. "Adopting Solar for Irrigation: Farmers' Perspectives from Uttar Pradesh." CEEW. January 2018. <https://www.ceew.in/publications/adopting-solar-irrigation-0>.
- Kaundinya, George Thomas/Ram. n.d. "Five Ways to Double Farmers' Income." @businessline. Accessed November 15, 2018. <https://www.thehindubusinessline.com/opinion/five-ways-to-double-farmers-income/article23827672.ece>.
- Khan, Khursheed A. 2014. "Crisis of Agricultural in Uttar Pradesh: From Apprehension to Actuality," 12.
- Khokhar, Tariq. 2017. "Chart: Globally, 70% of Freshwater Is Used for Agriculture." Text. The Data Blog. March 22, 2017. <http://blogs.worldbank.org/opendata/chart-globally-70-freshwater-used-agriculture>.
- Kopf, Dan, and Preeti Varathan. n.d. "If Uttar Pradesh Were a Country." Quartz India. Accessed November 26, 2018. <https://qz.com/india/1094942/if-uttar-pradesh-were-a-country-where-would-it-rank-by-size-wealth-and-other-measures/>.
- Kumar, Sanjay, Sidharth Kashyap, Shailbala, VK Tyagi, and Mahavir Singh. 2018. "Technological Options to Enhance Sugarcane Production in Plains of Uttarakhand." *Journal of Pharmacognosy and Phytochemistry* 7 (1): 1873–74. <http://www.phytojournal.com/archives/2018/vol7issue1S/PartAB/SP-7-1-472.pdf>.
- Kumar, Vinod. 2013. "Uses and Importance of Sugarcane." Agropedia. January 24, 2013. <http://agropedia.iitk.ac.in/node/38743>.
- Kumari, Maina, O.P. Singh, and Dinesh Chand Meena. 2017. "Crop Water Requirement, Water Productivity and Comparative Advantage of Crop Production in Different Regions of Uttar Pradesh, India." *International Journal of Current Microbiology and Applied Sciences* 6 (7): 2043–52. <https://doi.org/10.20546/ijcmas.2017.607.242>.
- Lahiry, S.C. 2018. "Climate Change and Its Impact on Water Resources." India Water Portal. April 3, 2018. <http://www.indiawaterportal.org/articles/climate-change-and-its-impact-water-resources>.
- Lodrick, Deryck O., and Nafis Ahmad. 2018. "Ganges River." *Encyclopedia Britannica*. Encyclopedia Britannica, Inc. <https://www.britannica.com/place/Ganges-River>.
- Mahal, Dinabandhu, and Vidula Anil Adkar. 2016. "Impact of Non-Performing Assets on Profitability and Productivity with Special Reference to Janata Sahakari Bank Ltd." *KHOJ – Journal of Indian Management Research and Practices* 1 (01).
- "Major Crops of India." n.d. General Knowledge Today. Accessed November 18, 2018. <https://www.gktoday.in/gk/major-crops-of-india/>.



- Mani, Muthukumara, Sushenjit Bandyopadhyay, Shun Chonabayashi, Anil Markandya, and Thomas Mosier. 2018. *South Asia's Hotspots : Impacts of Temperature and Precipitation Changes on Living Standards*. South Asia Development Matters. Washington, DC: World Bank. <https://openknowledge.worldbank.org/handle/10986/28723>.
- "Members and Subscribers | ISEAL Alliance." n.d. Accessed December 1, 2018. [https://www.isealliance.org/community-members?f%5B0%5D=community\\_status%3A176](https://www.isealliance.org/community-members?f%5B0%5D=community_status%3A176).
- Ministry of Agriculture and Farmers Welfare. 2018. "Revised Guideline for Paramparagat Krishi Vikas Yojana (PKVY) Scheme," May 2018. <http://agricoop.nic.in/sites/default/files/Final%20PKVY%20revised%20guideline.%20.pdf>.
- Mohan, Vishwa. 2016. "To Beat Drought, ICAR Eyes GM Sugarcane." *The Times of India*, 2016. <https://timesofindia.indiatimes.com/india/To-beat-drought-ICAR-eyes-GM-sugarcane/articleshow/52180722.cms>.
- National Innovations on Climate Resilient Agriculture. n.d. "Agriculture Contingency Plan for District: Rampur, Uttar Pradesh." Accessed December 6, 2018. <http://www.nicra-icar.in/nicrarevised/index.php/state-wise-plan>.
- "National Mission for Sustainable Agriculture." 2016. Government of India Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare. <http://www.agriclinics.net/NMSA.pdf>.
- NITI Aayog. 2017. "Road Map of Pradhan Mantri Krishi Sinchayee Yojana."
- Nowak, Southard. 2017. "Working to Help Train More Than 100,000 Sugarcane Farmers in India." The Coca-Cola Company. August 16, 2017. <https://www.coca-colacompany.com/stories/working-to-help-train-more-than-100-000-sugarcane-farmers-in-india>.
- "Nutrient Loadings and Eutrophication." n.d. NYS Dept. of Environmental Conservation. Accessed December 3, 2018. <https://www.dec.ny.gov/chemical/69489.html>.
- Oakley, Peter, and Christopher Garforth. 1983. "Social and Cultural Barriers to Agricultural Change." FAO. October 1983. <http://www.fao.org/docrep/t0060e/T0060E04.htm#Social%20and%20cultural%20barriers%20to%20agricultural%20change>.
- Pandey, Apurvaa. 2018. "The Hidden Price of Interlinking Rivers in India." *Geopolitical Monitor*. February 1, 2018. <https://www.geopoliticalmonitor.com/the-hidden-price-of-interlinking-rivers-in-india/>.
- Pandey, Vinay Kumar, and Ajai Mishra. 2015. "Causes and Disaster Risk Reduction Measures for Hydrometeorological Disaster in Uttarakhand, India: An Overview." *International Journal of Current Research in Science and Technology* 1 (3): 61–80. <http://ijcrst.in/v1n3.html>.
- Paranjothi, T, and H Misra. 2017. "Dhundi Solar Pump Irrigators' Cooperative: A Preliminary Study." International Co-op Alliance. <http://www.ica-ap.coop/icanews/dhundi-solar-pump-irrigators-cooperative>.
- Pfly. 2011. "The River Ganges." Creative Commons. [https://commons.m.wikimedia.org/wiki/File:Ganges-Brahmaputra-Meghna\\_basins.jpg](https://commons.m.wikimedia.org/wiki/File:Ganges-Brahmaputra-Meghna_basins.jpg).

- PTI. 2018. "World Bank Says India Has Huge Potential, Projects 7.3% Growth in 2018," January 10, 2018.
- — —. n.d. "Cabinet to Vet Rs 48K Cr KUSUM Scheme for Solar Power by March - Times of India." The Times of India. Accessed November 15, 2018.  
<https://timesofindia.indiatimes.com/business/india-business/cabinet-to-vet-rs-48k-cr-kusum-scheme-for-solar-power-by-march/articleshow/62996439.cms>.
- Rawat, Virendra Singh. 2016. "IISR Developing Sugarcane Varieties for Water-Stressed Environment." *Business Standard India*, May 16, 2016. [https://www.business-standard.com/article/economy-policy/iisr-developing-sugarcane-varieties-for-water-stressed-environment-116051600674\\_1.html](https://www.business-standard.com/article/economy-policy/iisr-developing-sugarcane-varieties-for-water-stressed-environment-116051600674_1.html).
- Raymond, Anne, and Abhishek Jain. 2018. "Solar for Irrigation, A Comparative Assessment of Deployment Strategies." CEEW. <https://www.ceew.in/publications/solar-irrigation>.
- Ross, Katherine, and Rhys Gerholdt. 2017. "Achieving India's Ambitious Renewable Energy Goals: A Progress Report | World Resources Institute." May 12, 2017.  
<https://www.wri.org/blog/2017/05/achieving-indias-ambitious-renewable-energy-goals-progress-report>.
- Saleth, R. Maria, and International Water Management Institute. 2004. "Strategic Analysis of Water Institutions in India: Application of a New Research Paradigm." 79. Colombo, Sri Lanka: International Water Management Institute.  
<http://ageconsearch.umn.edu/bitstream/44545/2/Report79.pdf>.
- Sapovadia, Vrajlal, and Sweta Patel. 2012. "Humanization: Explaining the Law of Cooperatives in India." Munich Personal RePEc Archive. <http://mpa.ub.uni-muenchen.de/44109/>.
- Shah, Tushaar, Neha Durga, Gyan Prakash Rai, Shilp Verma, and Rahul Rathod. 2017. "Promoting Solar Power as a Remunerative Crop." *Economic and Political Weekly*, no. 45: 6.  
<https://www.epw.in/journal/2017/45/commentary/promoting-solar-power-remunerative-crop.html>.
- Shah, Tushaar, and Dharini Parthasarathy. 2015. "Why India's Leap into the Solar-Powered Age Must Take along Farmers | CCAFS: CGIAR Research Program on Climate Change, Agriculture and Food Security Solar-Powered Pumps for the Farm Sector." March 4, 2015.  
[https://ccafs.cgiar.org/blog/why-india%E2%80%99s-leap-solar-powered-age-must-take-along-farmers#.W\\_RwOJNKigw](https://ccafs.cgiar.org/blog/why-india%E2%80%99s-leap-solar-powered-age-must-take-along-farmers#.W_RwOJNKigw).
- Sharma, Bharat, Ashok Gulati, and Gayathri Mohan. 2018. "Water Productivity Mapping of Major Indian Crops." NABARD.  
[https://www.nabard.org/auth/writereaddata/tender/1806181128Water%20Productivity%20Mapping%20of%20Major%20Indian%20Crops,%20Web%20Version%20\(Low%20Resolution%20PDF\).pdf](https://www.nabard.org/auth/writereaddata/tender/1806181128Water%20Productivity%20Mapping%20of%20Major%20Indian%20Crops,%20Web%20Version%20(Low%20Resolution%20PDF).pdf).
- Sharma, G.K., and W.I. Khan. n.d. "A Study of Cooperative Legislations in Selected Asian and Pacific Countries." Fao.Org. Accessed December 7, 2018.  
<http://www.fao.org/docrep/007/AD713E/AD713E03.htm>.

- Sharma, Prakriti. 2017. "5 Most Water Intensive Crops." *Claro Energy Private Limited* (blog). July 24, 2017. <http://claroenergy.in/5-most-water-intensive-crops/>.
- Sharma, Pravesh. 2017. "Agricultural Market Reforms: Back to the Future in the Mandi Again | The Indian Express." *Indian Express*, May 11, 2017. <https://indianexpress.com/article/india/agricultural-market-reforms-back-to-the-future-in-the-mandi-again-4650332/>.
- Siel Limited. 1997. "India." In *International Sugar Conference: India*. <http://www.fao.org/docrep/005/X0513E/x0513e20.htm>.
- Singh, Anil Kumar, Avtar Singh Jasrotia, Ajay Kumar Taloor, Bahadur Singh Kotlia, Vaibhav Kumar, Sagarika Roy, Prashant Kumar Champati Ray, Kamallesh Kumar Singh, Anoop Kumar Singh, and Arun Kumar Sharma. 2017. "Estimation of Quantitative Measures of Total Water Storage Variation from GRACE and GLDAS-NOAH Satellites Using Geospatial Technology." *Quaternary International*, Third Pole: The Last 20,000 Years - Part 2, 444 (July): 191–200. <https://doi.org/10.1016/j.quaint.2017.04.014>.
- Singh, Mamata. 2005. "Only 42% PDS Grain Reaches the Poor." Rediff.Com. June 16, 2005. <http://www.rediff.com/money/report/pds/20050616.htm>.
- Singh, S N, Pushpa Singh, R K Rai, and A D Pathak. 2018. "Vegetables Intercropping with Autumn Planted Sugarcane:," 4.
- Solomon, S. 2014. "Sugarcane Agriculture and Sugar Industry in India: At a Glance." *Sugar Tech* 16 (2): 113–24. <https://doi.org/10.1007/s12355-014-0303-8>.
- . 2016. "Sugarcane Production and Development of Sugar Industry in India." *Sugar Tech* 18 (6): 588–602. <https://doi.org/10.1007/s12355-016-0494-2>.
- Srinivasa Rao, Cherukumalli, Rattan Lal, Jasti V. N. S. Prasad, Kodigal A. Gopinath, Rajbir Singh, Vijay S. Jakkula, Kanwar L. Sahrawat, Bandi Venkateswarlu, Alok K. Sikka, and Surinder M. Virmani. 2015. "Chapter Four - Potential and Challenges of Rainfed Farming in India." In *Advances in Agronomy*, edited by Donald L. Sparks, 133:113–81. Academic Press. <https://doi.org/10.1016/bs.agron.2015.05.004>.
- "State Profile." n.d. Department of Horticulture, Government Of Uttarakhand, India. Accessed December 3, 2018. <http://shm.uk.gov.in/pages/display/6-state-profile>.
- "Status Paper on Sugarcane." 2017. Government of India Ministry of Agriculture. [http://www.sugarcane.dac.gov.in/StatusPaper/SP\\_Sugarcane2017.pdf](http://www.sugarcane.dac.gov.in/StatusPaper/SP_Sugarcane2017.pdf).
- Sugar Industry & Cane Development Department. n.d. "Sugarcane Development Cooperative Societies, Uttar Pradesh, India." Accessed November 27, 2018. <http://upcane.gov.in/StaticPages/SDCSAbout.aspx>.
- "Sugarcane - History and Facts of Sugarcane." n.d. Sugar History. Accessed November 12, 2018. <http://www.sugarhistory.net/sugar-making/sugarcane/>.

- The Economist*. 2018. "India's Government Claims to Subsidise Farmers, but Actually Hurts Them," July 12, 2018. <https://www.economist.com/asia/2018/07/12/indias-government-claims-to-subsidise-farmers-but-actually-hurts-them>.
- The Hans India*. 2018. "Top Contributors to GDP," June 19, 2018, Hyderabad edition. <https://www.thehansindia.com/posts/index/Hans-Classroom/2018-06-19/Top-contributors-to-GDP/390359>.
- Tripathi, Ravindra, and Sweta Agarwal. 2015. "Rural Development through Agripreneurship: A Study of Farmers in Uttar Pradesh." *Global Journal of Advanced Research* 2 (2): 534–542.
- "Uttarakhand State Action Plan on Climate Change." 2014. Government of Uttarakhand. [http://sccc-uk.org/reports/publish2Uttarakhand%20SAPCC\\_XPS310816695.pdf](http://sccc-uk.org/reports/publish2Uttarakhand%20SAPCC_XPS310816695.pdf).
- "Uttarakhand State Perspective and Strategic Plan 2009-2027." n.d. Watershed Management Directorate, Dehradun. [http://wmduk.gov.in/Perspective\\_Plan\\_2009-2027.pdf](http://wmduk.gov.in/Perspective_Plan_2009-2027.pdf).
- VectorStock. 2018. "Detailed Map of India Asia with All States and Vector Image." VectorStock. 2018. <https://www.vectorstock.com/royalty-free-vector/detailed-map-of-india-asia-with-all-states-and-vector-19238857>.
- Verma, Anju, Biswajeet Thakur, Shashwat Katiyar, Dharam Singh, and Madhu Rai. 2013. "Evaluation of Ground Water Quality in Lucknow, Uttar Pradesh Using Remote Sensing and Geographic Information Systems (GIS)." *International Journal of Water Resources and Environmental Engineering* 5 (2): 67–76. <https://doi.org/10.5897/IJWREE11.142>.
- WaterAid. 2016. "Assessment of Impact of Drought on Men, Women and Children."
- World Bank. 2013. "Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience." A report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics. Washington, DC.

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#### Appendix D.1. COVER AND DIVIDER PHOTO CREDITS

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