BuyBy

Yale University
Stanford University

Abstract

The burning of residual crop stubbles is a common agricultural management method practiced worldwide by small- and medium-holder farmers. It represents a cheap and fast alternative to the labor-intensive manual and automated treatment of crop stubbles. Constituting more than one-third of the global emission from biomass incineration, stubble burning is also an important driver of air pollution, soil degradation, and climate change. Despite policy interventions, it remains common practice in many regions of the world.

To overcome this issue, we propose a software-based marketplace solution that enables farmers to sell these crop stubbles and other by-products to generate alternative income. The marketplace is designed to be easy-access and avoid common entry barriers to rural and uneducated farmers, such as trust issues or illiteracy. By offering price guidance on various products, we aim to provide sufficient financial incentive to discourage open stubble burning and popularize a circular approach to agricultural management.

At the example of the Punjab region in India, we demonstrate the viability of the solution. Through stakeholder interviews, an extensive literature review, and market analyses, we establish the need for an intervention and validate the concept of the platform. In a further step, we outline the design and the steps required for its successful implementation.

The Team

Elaine Lac studies Environmental Management at the Yale School of the Environmental, specializing in Industrial Ecology, Green Chemistry, and Business. She has worked as a Peace Corps Volunteer in Senegal in Urban Agriculture, a grassroots organizer in Kentucky and Los Angeles, a policy and legislation advocate in Washington, D.C., and a GIS Specialist. Elaine is from the United States.

Maximilian Schubert studies Environmental Management at the Yale School of the Environment. He specializes in Green Finance, Business, and Industrial Ecology. Before, he has worked as a consultant for the Food and Agriculture Organization of the United Nations in Rome and with Deloitte Sustainability Consulting in Munich. He did his bachelor's in Forestry and Landscape Management in Freiburg, Germany.

Yiwei (Viviana) Li studies Asset Management at Yale School of Management, specializing in private capital and impact investing. Before SOM, she has worked as a market analyst in L'Oréal's strategy team in Paris, a business intelligence intern at UN Peacekeeping Operations in New York, and a consultant and a development finance researcher in Toronto. Viviana is from Canada.

Veenu King studies Environmental Management at the Yale School of the Environment. She specializes in Business and Industrial Ecology. She has worked as a data scientist and supply chain consultant for a tech start-up in Los Angeles and completed her Bachelors in Operations Research and Financial Engineering from Princeton University. Veenu is from the United States.

Stefan Faistenauer studies Management Science and Engineering at Stanford University, specializing in venture development and engineering management. He interned as a Product Manager at Google Flights and co-organizes a Principled Entrepreneurship course at Stanford. Stefan grew up in Austria and received his bachelor's degree from the Technical University of Munich.

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1. Introduction

According to the World Health Organization's Global Burden of Disease report (2016), 90% of humanity breaths air that exceeds WHO guideline limits for contamination, the majority of which lives in developing countries (World Health Organization, 2016). The negative health effect, from skin and eye irritation to chronic respiratory disease and cardiovascular illness, resulting from long-term exposure, can lead to premature deaths (Abdurrahman et al., 2020). In China alone, this condition causes 1.1 million deaths and a loss of 21.8 million years due to a shorter life expectancy annually (Cohen et al., 2017). Globally, it amounts to a death toll of 7 million people, more than 19,000 a day (World Health Organization, 2016).

One major contributor to this air pollution is the burning of residual stubbles after crop harvest. It is a common management practice found in many regions of the world but finds it hotspots in developing and emerging economies, which makes up more than 60% of all biomass burnt (Streets et al., 2003; T. Zhang et al., 2015). For example, 84 Mt of stubbles are incinerated on the open field in India every single year, emitting more than 1.2 Mt of particulate matter and 100 000 tons of NOx gases (Abdurrahman et al., 2020). Consequently, the open burning of stubbles represents an integral part of air pollution worldwide (H. Zhang et al., 2011).

Beyond the detrimental impacts on air quality, such a practice further feeds into two major crises directly. On the one hand, it promotes soil degradation as it scorches soil's organic content, raises its pH level, and destroys the soil structure (Chan & Heenan, 2005; Singh & Sarkar, 2021). To date, the Food and Agriculture Organization of the United Nations (FAO) estimates that 35% of the world's soils are moderate to highly degraded, leading already to food insecurity and biodiversity loss (FAO, 2015). On the other hand, it is a significant driver of climate change (Levine et al., 1995). Stubble burning constitutes more than one-third of the global emissions from biomass burning (Levine et al., 1995). The massive use of this practice leads to observable increases in aerosols, SO_2, and NO_2 emissions (Mittal et al., 2009; H. Zhang et al., 2011) and ozone depletion (Singh & Sarkar, 2021).

Several countries and regions are restricting stubble burning with policies (Air Act, 1987/2019; 603-077-0101, 2009; EU CAP, 2013; The Crop Residues (Burning) Regulations No. 1366, 1993), but the problem persists for a variety of reasons (T. Zhang et al., 2015). Regionally, crop stubble burning has even increased (Environment Ministry India et al., 2020; Levine et al., 1995) as this practice offers many short-term advantages over alternative crop management methods.
It enables farmers to quickly free up their fields and prepare them for the next crop, saving valuable time in their rice-wheat crop rotation (Mittal et al., 2009). The burning clears the field and acts as an effective pest control and prevention measure (Grains Research and Development Corporation, 2018; Singh & Sarkar, 2021). Furthermore, it is significantly cheaper than the manual removal or the lease of a special machine (Jain et al., 2021). Lastly, by incinerating these left-overs, farmers avoid having to deal with large amounts of stubbles. For instance, a typical wheat-rice cropping system in India produces 7-10t of crop residues per hectare every year, more than half of which stems from rice (Mandal et al., 2004). But the high lignin and low nutrient content of rice stubbles make them undesirable to use as fodder (Gummert et al., 2020), leading to 75% of the rice stubble being burnt openly (Devi et al., 2017), emitting as much as 13 tons of CO_2 per hectare of stubbles (Mandal et al., 2004).

In consequence, stubble burning represents undeniably an often overlooked yet major contributor to several global crises that threaten the livelihoods of billions of people today and in the future worldwide.

In this paper, we propose a platform-based management method following the principles of Industrial Symbiosis. This concept aims to create synergies by utilizing by-products for value-creation and therefore avoiding waste (Chertow, 2000). We apply the platform solution to the case of the Punjab region in India. The state finds itself annually in the reoccurring global spotlight as the September winds transport the smoke of stubble burning activities south, where they can make up 40% of Delhi's prominent air pollution problem that caused 54,000 deaths in 2020 (Environment Ministry India et al., 2020; Greenpeace SEA et al., 2020). Furthermore, the farmer protests responding to agricultural reforms in India have made continuous international headlines since their reception in 2020 (Khosla & Milliff, 2021; Mashal et al., 2021), further exacerbating the situation on the ground. Although we acknowledge particular political and environmental circumstances that apply solely to this region, the proposed solution can be a broader concept replicable in other parts of the world.

2. Geographic Region Overview

The Country of India

GNI per capita: 1,800 USD

Population: 1,330,637,000

Urban: 34%
Rural: 66%

Classified as a lower-middle income economy by the World Bank.

Access to Smartphones: 760 million (67%)

Farmer population: 100-150 million

Agriculture contributes 18% of India's overall GDP and 41.49% of the population rely on agriculture as their primary source of income.

50-75 million farming households engage in at least two growing seasons and hold an average of 1.08 hectares of land.

(Bhardwaj and Singh, 2021; Damodaran, 2021; Maps of India, 2020; Statista, 2020)

2.1 Geographic Background Context

In 1966, India strove to become a food independent nation and achieved this by extending agricultural technologies such as improved high yield crop varieties and irrigation infrastructure to Punjab, Haryana, and the Western Uttar Pradesh region. This ushered India into a green revolution and independence from food aid. In 1965, the Food Corporation of India was established and implemented a Minimum Support Price (MSP) for farmers to recoup the cost of production for crops selected by the Commission of Agricultural Cost and Prices (CACP) (Gulati et al., 2021). Under this system, the government became the largest purchaser of staple MSP crops and price guarantor. These staple MSP crops were sold to the poor at discount subsidized rates (Sharma, 2020). Mandis were also created as regulated agricultural markets where farmers could sell their goods through commission agents or arthiyas. Arthiyas handle transactions and negotiations with buyers on the behalf of farmers and are often done without documentation and can lead to farmer exploitation. The highly regulated agricultural system was well-intentioned but has led to a minimal investment transportation infrastructure, limited access to buyers outside mandis, and low-price transparency (Levi et al., 2020).

The Punjab region is one of the most fertile regions of India. It contributes more than 50% of India's wheat and more than 40% of its rice (Vattal, 2014). Agriculture employs over 30% of the population, and the region has played a critical role in achieving food security (Gulati et al., 2021; Vattal, 2014). Moreover, the MSP for wheat and rice has created an incentive for farmers to focus on producing wheat and paddy/rice despite unfavorable soil, climate, or degrading air quality (Gulati et al., 2021). In this two-crop rotation system, rice, also known as a Kharif crop, is planted in May and is harvested in October, while wheat, a rabi crop, is planted in December and harvested in April. The average period between rice harvest and wheat sowing is 15 days. Burning is employed to transition quickly between rice and wheat (Abdurrahman et al., 2020). This practice is deemed cheaper and faster than hand tilling or using mechanized tillers, Happy Seeders, which are being subsidized by the local government (Goyal, 2019). The government has also attempted to curb stubble burning by offering Rs 2,500 per acre of land that farmers did not burn in 2020; however, the government's failure to make the subsequent payment has degraded confidence in the government and encouraged stubble burning (Bhatia, 2020).

Unlike average farm holding sizes in India (1.08 hectares), Punjab farmers have higher than average land holdings at 3.65 hectares. However, these landholdings are diminishing (Agricultural Census, 2015-16). Punjab farmers' financial security has waned after 2005 due to diminished land holdings and decreased productivity (Gulati et al., 2021). Farmers have been forced to sell off their land to relieve increased debt (Rai, 2020). The diminishing of landholding threatens the future livelihood of farmers, which means increasing productivity is essential to securing financial stability.
In September 2020, the Indian Government introduced a series of Agricultural Acts, also known as Farm Bills, to promote free-market liberalization of the agricultural sector by removing MSPs and APMC controlled mandis.

However, farmers in the Punjab region have collectively rejected these acts because they were viewed as a threat to farmer's financial security, autonomy, and consumer protections (Sharma, 2020). Thereinto, Punjab has passed state-specific amendments, which continue MSPs for wheat and paddy and reimposed fines to sellers and buyers outside of the APMC (Sharma, 2020). Punjab farmers' unwillingness to adapt these Acts perpetuates the status quo of wheat-paddy rotation farming, which will continue to further degrade soil health and air quality.
We selected the northern region of Punjab as the pilot for our project due to the following reasons: the importance of agriculture to local economy, policy changes, and the need for regenerative agricultural practices.

Punjab Province of India

Indian province with 22 districts.

Population: 30.49 million

413,000 hectares of land are used for agricultural cultivation and called India's breadbasket.

Produces:

12% of India's rice

17% of India's wheat

5% of India's milk

Agriculture generates 25% of Punjab's GDP.

Average land holdings are 3.62 hectares.

70% of the population use smartphones or Internet.

(Bhardwaj and Singh, 2021; Maps of India, 2019; Ministry of Agriculture & Farmers Welfare, 2019a; Ministry of Agriculture & Farmers Welfare, 2019b; Statista, 2020; Punjab Population, 2020; Punjab Budget Analysis 2020-21, 2020; Roy, 2019)

3. Needs Assessment

3.1 Literature Review

Broadly, India has been affected by climate change, and agricultural productivity is anticipated to decline as climate change effects become more prominent. According to the RCP 1.5 climate change scenario, Punjab is projected to lose 6 to 8% of its agricultural productivity by 2030, and such a loss will increase to 15 to 17% in 2050. Additionally, Punjab has experienced rising wealth inequality, and the unequal burden of climate change will be borne unequally by lower-earning individuals such as smallholder farmers (Colenbrander, 2021).

Further contributing to reduced agricultural productivity is the decline of soil quality. Stubble burning removes essential nutrients in the soil and requires the reapplication of compost and fertilizer to restore lost soil fertility. It also releases SO2, which leads to acid rain formation, further reducing agricultural productivity (Abdurrahman, 2020). Policy reforms, such as the Farm Bills, attempt to introduce market liberalization to promote crop diversity, price transparency, and a transition from government subsidized agriculture. These reforms seek to shift the current unsustainable two crop rotation using market mechanisms. But the Punjab region is resistant to these reforms because of distrust in the market and potential loss of financial security (Sehgal & Rai, 2020). Research has shown that policy, while an essential step to addressing agricultural productivity, is insufficient and solutions instead require multipronged approaches incorporating infrastructure, technical skill extension, and regenerative agricultural practices (Lencucha et al., 2020).

3.2 Stakeholder Needs Assessment

Based on stakeholder engagement, fieldwork, literature and research review, and interviews with experts from the area and on the topic have led us to identify the needs which have guided our project design. The themes that have come from these interviews reveal that the prevailing issues that farmers in India broadly and in Punjab face are decreasing tracts of land, inadequate financial incentives, lacking logistical infrastructure, and diminishing soil health.

Small shareholder farmers face rising debt, water scarcity, and depleting soil quality in addition to air pollution from stubble burning. Generally, small shareholder farmers lack assured financial security due to opaque financial transactions completed by arthiya middlemen (Rathod, 2021). Market controls such as Minimum Support Pricing and APMCs are discouraging farmers from diversifying crops. The APMC Act enforced in Punjab perpetuates the MSP and incentivizes wheat and rice cash crop growing rather than diversification to other high-value items such as fruits and vegetables (Singh, 2011). Before the Farm Bill, the government fulfilled procurement and transportation roles, allowing farmers to get their products to market. Now, farmers need or must create their own economies of scale and supply chain infrastructure to bring products to market without the assistance of the government and its subsidies (Balani, 2021).

Individuals have attempted to close these gaps by starting farmer producing organizations and creating online platforms which connect farmer suppliers to buyers such as supermarkets and restaurants. Adopting an online platform-based solution faces several barriers. 30 percent of farmers in India are still illiterate, and sensitization is needed to familiarize farmers with an interface even if they are aware of digital marketplaces or digital wallets (Bose, 2019). Most financial transactions between farmers remain cash based. This is coupled with farmer's distrust in the government and buyers to follow through with payments (Agarwal, 2020; Goyal, 2019).

4. Market Needs and Gap Analysis

4.1 India National and Punjab-region Market Overview

Agri-tech, the intersection of two industries - agriculture and technology, presents viable growths and lucrative business opportunities that attract public and private, domestic and international organizations to enter. In recent years, the agri-tech sector in India has attracted renewed investors and local government's interest. This trend is largely driven by the attractiveness and resilience observed in the intersection of the agriculture and technology industries. On one side, the agriculture sector in India employs approximately 60% of the employable population, contributing to 18% of the total GDP (Statista, 2021). On the other hand, the IT-BMP industry is one of the fastest-growing industries in India, accounting for 8% of the nation's GDP in 2020 (IBEF, 2021). According to Ernest & Young's market studies, the agri-tech market in India has predicted to reach $24 billion by 2025 (Puhwa, 2020). As of August 2020, Indian agri-tech companies have raised $532 million (Kashyaap, 2021). Observing the rapidly growing trends in the agri-tech sector, our team set out to explore the potential of developing an agri-tech solution, which comprises a technological platform for the exchange of agricultural by-products to address stubble burning issues in India.

Moreover, the agri-tech sector in the Punjab region has gained increasing traction amongst investors and entrepreneurs. Many Punjab-based agricultural startups are working to enhance farmers' livelihood through the integration of technology. However, many of these startups focus on using technologies to improve the quality of yields, cost optimization, and food traceability (Roy, 2019). Additionally, these companies tend to have a nationwide scope of operations, despite being Punjab-based organizations. Lastly, there are already several established players in the Indian agri-tech industry. Each player possesses a unique proposition that involves different stakeholders and specializes in a particular sub-agricultural goods or technological solutions. Currently, there are finite numbers of agri-tech companies with a business scope that involve a broad range of agriculture by-products to promote a circular economy. This presents a distinct need for us to fill. Our solution's exclusive focus on industrial symbiosis strongly differentiates us from existing market offerings.

To ensure the success of our solution upon launch, we first need to understand the existing product offerings in the market to pinpoint market discrepancies and inefficiencies that can be addressed with our devised solutions. As indicated earlier, the agri-tech sector is a nascent field with rising innovations. Many organizations in this space are relatively young and unstable. Consequently, we have identified several established players in the Indian agri-tech industry to understand their business models.

Existing Players	About	Specialization/Focus	Geographic Coverage	Agri-product involved
Ninjacart	India's largest fresh produce supply chain company. A B2B fresh foods supply chain company that connects farmers directly to customers through a technology-driven integrated supply chain.	It connects food producers directly with retailers, restaurants, and service providers using in-house applications that drive end-to-end operations. The current supply chain equips to transport 1400 Tonnes of perishables from farms to businesses every day in less than 12 hours	Most major India cities	Perishable goods
Agrostar	AgroStar solves the traditional farmer problems faced around duplication, adulteration, and product unavailability by making a wide range of agro-solution available to farmers through a simple missed call.	It provides agronomy advice, data analytics, technology, and agri-inputs to farmers. Through its APP or call center services, farmers can access personalized, agri-focused content, and articles focused on helping farmers grow better to produce and solve common problems in the farm.	Gujarat, Rajasthan, and Maharashtra	Farmers can browse through a wide variety of quality products like seeds, crop protection, nutrition, and farm implements belonging to the best agri-brands in the country.
Stellapps	Stellapps An end-to-end diary solutions company working toward the digitalization of diary supply chain	Stellapps is provides a comprehensive services portfolio that optimizes the agricultural supply chain across milk production, milk procurement, cold chain, animal insurance, and farmer payments, which has led to higher milk yields, reduce pilferage, better herd health and lower insurance costs.	Nationwide	Dairy products (e.g., fresh milk, cheese, yogurt, etc.)
Jumbotail	India's leading wholesale food and grocery, and a new retail platform.	It connects any brands (foreign and domestic) in India with local mom-and-pop, Kirana, stores and supermarkets		Not limited to agricultural products, including staples, personal and home care products, and packaged foods
Vegrow	An agri-tech startup focused on aggregating small farms. It wants to build the world's biggest asset-light farm by partnering with small farmers on a profit-sharing model	Vegrow increases the net earnings of partner farmers by exploiting technology across different stages of the farming cycle. It helps farmers in crop planning, provide access to quality inputs, monitors their adherence to best practices, and ultimately sells harvest to the right buyers.	Nationwide	Horticultural goods
Cropin	Cropin is a leading global artificial intelligence and data-led agri-tech organization empowering stakeholders to reimagine agriculture with data.	It provides decision-making tools and platform solutions that bring consistency, dependability, and sustainability to agri-business. It also works with clients to digitize farms while data-managing the entire ecosystem. It hopes to democratize data for all stakeholders of the industry and empowers them to benefit from data-driven farming.	Nationwide	4 digital/SaaS solutions: SmartFarm, SmartRisk, SmartWare, and RootTrace

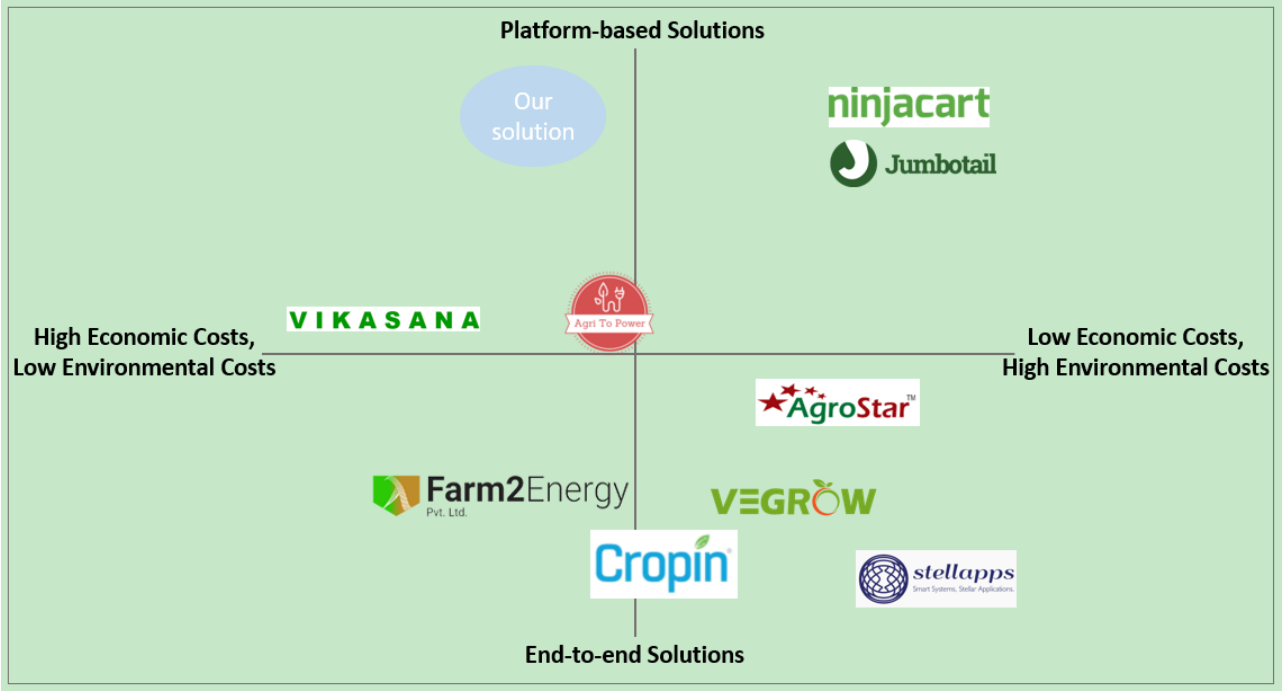
E-Nam	A pan-India electronic trading portal, started by the Government of India, intends to unify the national market for agricultural commodities. It also provides a single-window service by networking existing APMCs.	It provides a real-time price discovery function and facilitates trades. Payments are made online via electronic payment methods. E-Nam covers a few markets (APMCs) in Punjab, and most produce traded on the platform from Punjab are corns, maize, pea, and potato.	Nationwide	A comprehensive list of commodities available on the platform.
Agri2Power	A2P is working towards resolving the paddy straw burning problem by putting up sustainable projects for converting the straw into useful products like Energy and Soil Conditioners.	A2P provides services to both downstream and upstream services. It sources and procures paddy straw by interacting with villagers and baler owners. It then manufactures pellets from paddy straw, a source of biofuel, and sells these fuel pellets to the industry to fuel their boilers.	Punjab	Paddy straw

4.2 Current Market Offerings and Agri-tech sector Landscape

Building upon previous research on existing market offerings, we have developed the following market landscape map that categorizes highlighted companies accordingly along two dimensions: platform-based solutions versus end-to-end solutions and high economic costs with low environmental costs versus low economic costs with high environmental costs. We have determined that the existing, established agri-tech companies usually focus on providing either a platform-based solution or an end-to-end digital solution. Additionally, in terms of impact orientation, some market offerings prioritize improving farmers' and/or smallholder farmers' quality of life by increasing their income levels. This indicates a comparatively low internal economic cost, but there might be potential neglect or ignorance on their impacts on the environment, resulting in high external environmental costs. In contrast, some organizations have positioned themselves to generate higher environmental impact at the expense of higher internal economic costs, reaping from the advantage of lower external costs.

As highlighted on the map, there is an open space in the upper left quadrant, indicating a lack of product offerings that deliver a combination of high environmental impacts and platform-based solution in the current market. As well, given farmer's reservations toward government-driven initiatives and the downside risk of invading governmental trusts, it is deemed more viable to devise a non-policy solution. Deriving from these insights, we sought to create a market-based solution that serves the dual purposes of filling in the current market need and addressing the stubble-burning crisis in the Punjab region. With that, there are three levels of impacts we aim to generate: to reduce stubble-burning activities in the Punjab region, provide an additional source for smallholder farmers, and eventually promote a sustainable agricultural practice that leads to a circular economy.

With such unique propositions, there is one potential competing offering, AgriToPower. But its business model offers neither a marketplace nor an end-to-end solution. It focuses solely on collecting paddy straws and transforming them into burnable pellets sold to biofuel companies. Although AgriToPower also seeks to address stubble-burning issues, its only downstream clients are in the energy sector. Our solution differentiates from AgriToPower in two ways. First, our marketplace allows diverse agriculture by-products to be sold on the platform. This increases the viability for different farmers to participate on our platform and benefit from the supplementary income generated from stopping stubble burnings. Secondly, our platform allows diverse downstream clients, such as sustainable textile manufacturers and other biofuel companies, to connect with farmers on the platform beyond AgriToPower's single clientele stream. We anticipate our solutions will generate higher economic incentives and environmental impacts based on broader product scope and a wider target audience base.



(Figure: Market Landscape Map)

4.3 Similar Product Offerings

In addition to the private enterprises currently operating on the field, two other noticeable organizations operating in our selected quadrants of high economic costs and low environmental costs. Vikasana and Farm2Energy. Vikasana is an NGO working for sustainable agriculture with a program dedicating to agro-waste management. The program collects sixty to seventy percent of agricultural wastes from farmers and pays approximately Rs 500 per tonne of residue collected. Under the assumption that one acre of agricultural land generates approximately four to five tonnes of waste, farmers who participate under Vikasana's program can earn an additional Rs 1,500 to Rs 2000 income monthly (Roopa, 2019). Vikasana aims to engage more farmers to meet the increased demands for biomass (Roopa, 2019). Our solution differentiates itself from Vikasana by providing a digital marketplace that facilitates exchanges between farmers and corporations at a greater autonomy and eliminates middlemen that might distort farmers' profitability and increase logistical complexity. Since there is no prerequisite for the type of agriculture by-products transacted on our platform, we expect diverse farmers and corporations to be engaged on our platform across geographies.

Another possible organization is Farm2Energy, a startup from Punjab that provides robust and integrated biomass supply solutions for the advanced biofuel and biopower industry. Under its existing business model, Farm2Energy collects stubble from farmers' fields free of charge and provides consulting services to farmers in growing, managing, and utilizing biomass (Roopa, 2019). It then processes paddy straw, corn stover, sugar cane trash, and wheat straw and supplies them to biofuels or bio-based energy companies via its integrated supply system (Roopa, 2019). One differentiating characteristic about Farm2Energy is that it is both a potential client and an indirect competitor to our solution. Farm2Energy can utilize our marketplace to collect a greater volume of agriculture by-products to support its operations. As well, Farm2Eneregy currently collects stubbles from farmers for free by performing the services itself. Using our marketplace solution can help reduce their operational costs associated with stubble collection. Consequently, we see it as a potential clientele for our services.

4.4 Market Demand Validation

Earlier sections in this paper have demonstrated a high level of underutilized supplies of agricultural by-product in the Punjab region, while the demand side of the equation remain ambiguous. To enhance the feasibility of our solution, our team sought to validate the level of demand for agricultural by-products in India.

First, to understand the demands, we reviewed academic literature on the industrial application of agro-waste or agricultural by-products. In a report published by Raddy and Yang, both scientists have indicated that by-products from the cultivation of corn, wheat, rice, sorghum, barley, sugarcane, pineapple, banana, and coconut are the major sources of agro-based bio-fibers (Reddy & Yang, 2005). There is a broad range of industrial applications for by-products. For example, fibers can be used to produce textiles and composites, pulp and paper, dyes, pigments and inks, and ethanol and other alcohols (Reddy & Yang, 2005). Deriving from these research insights, we have identified domestic and international players that are in demand for agricultural by-products to support their production.

Biofuel companies: Within the domestic market, there are rising levels of investments being made in India's energy sector. In India alone, the biodiesel (ethanol) market has been projected to grow from $2.5 billion to $7.38 billion by 2024 (Kennedy, 2019). In the prior six years ending in 2019, a remarkable $64 billion investment has been made in renewable energy in India (Jagannath, 2020). These investments focus on the establishment of green energy sources, such as biofuel companies. There is a broad spectrum of usage for biomass in the biofuel industry, from the development of biomass, performance testing, to marketing. Due to regulatory constraints, domestic firms or multinational biofuel companies (with offices in India) are most likely to engage on our platform first. A notable global company and a potential client of our solution are Fortum, a Finnish state-owned energy company. Fortum India has also signed an agreement with Chaudhary Charan Singh Haryana Agricultural University, Hisar to manufacture textile fiber from paddy straw (Ghosh, 2019). The success of such research will increase the demand for agricultural by-products in India.

Textile mills/producers: Altmat is an India-based textile research-lab-cum-producers that has transformed massive amounts of agriculture waste into natural fabrics and yarns (Whiting, 2021). These fibers and yarns will be used in textile and clothes productions. Given the estimated high demand for agro-waste products, Altmat is an ideal and suitable client for our platform. Beyond domestic companies, many foreign companies have developed technologies that can transform cellulosic fibers into fiber for the textile industry, such as Spinnova from Finland and Nanollose from Australia. Accompanying the global trend of increasingly environmentally conscious consumers, the demand for sustainable textile manufacturing goods is likely to increase. Since agriculture is one of the major sectors contributing to India's GDP, an increasing number of sustainable material companies will turn to our platform to connect with farmers and smallholder farmers in collecting agriculture by-products.

Converting agro-residuals to plates and fabrics: Bio-Lutions India is a Hamburg-based company with operations in Ramanagara, near Bengaluru, which purchases agricultural wastes from farmers and makes biodegradable packaging and tableware from them. Kriya Lab is another example of an India-based organization that converts crop stubbles, mainly rice straw, which does not have any market compare to wheat straw and bagasse (Roopa, 2019), into single-use fabric tableware.

Through research, our team has concluded that there will be a robust and consistent domestic market demand for agriculture by-products. This further enhances the viability of our solution in India, with the potentials for replication and scalability in other agriculture-reliant developing countries. There is also room for foreign companies to procure through our platform in the future. To reduce the complexity of our initial offering, we will focus on establishing relationships with domestic players to ensure a high adaptation rate.

5. The Opportunity

Investor and government interest in the agri-tech industry paired with the large agriculture sector and IT-BMP boom offers digital products a unique opportunity to address institutional, systemic, and environmental challenges that Indian farmers face today. As our market analysis has shown, there are agri-tech players increasing farmer productivity, providing national-wide solutions, managing agri-waste, etc.; however, there are still gaps that have yet to be filled.

To bridge those gaps, our team proposes *BuyBy(Products)*, a digital marketplace for agriculture by-products. Supported by India's agricultural policies and harnessing the digital transition, BuyBy promotes farmer autonomy, increases agricultural-waste circularity, and provides a state-specific solution that has the potential to expand regionally and beyond. BuyBy eliminates the middleman between farmers and by-product purchasers, protects farmers with a reasonable minimum (floor) prices, and allows farmers to set their goods' prices. Instead of relying on policy to minimize stubble burning or unsustainable management of agriculture waste, BuyBy incentivizes farmers to sell their waste for additional revenue streams, increasing their financial stability and reducing reliance on unkept government promises. Lastly, BuyBy has been conceptualized to address unsustainable agriculture waste management in States and Nations where agriculture plays a vital role in economic livelihood yet deleteriously affects the environment and people. Hence, in places with similar conditions and a transition towards agri-tech, we can see BuyBy expanding its adoption and influence.

6. Design Principles and Considerations

BuyBy is a digital marketplace that allows farmers with harvest by-products to generate alternative sources of revenue by selling by-products instead of burning them or throwing them away. It serves to inform farmers of alternatives to burning harvest waste/by-products.

The tool, available as a mobile and desktop application, would allow farmers to register their harvest by-products and lock in buyers ahead of time, ensuring financial security and sufficient planning time. Simultaneously, buyers will be provided with a centralized marketplace of suppliers for material inputs. BuyBy's main stakeholders are farmers with smartphones and buyers looking to use agricultural waste as inputs.

6.1 Designing for Policy

Current policies enable BuyBy to be a solution tailored to farmers' and the economy's needs. India's Agricultural Export Policy 2018 supports the development of a "digital agri-stack enabling online marketplace and smart agriculture" (Hassan, 2020). Thus, enabling us to explore online marketplace-based solutions. Additionally, the Essential Commodities (Amendment Act) 2020 and the Farmers' Produce Trade and Commerce (Promotion & Facilitation) Act 2020 grants farmers the freedom to "hold, move, distribute, and supply food produce" and to sell to buyers outside of mandis for "barrier-free" trade (Hassan, 2020). These policies expand farmers' consumer base, increasing their leverage for more financial stability and autonomy. With this policy foundation, we envision BuyBy's online marketplace for by-products to spark a transition from current harmful agricultural and business practices to ones that are less abrasive and more sustainable for farmer livelihoods and the environment.

6.2 Designing for Trust

As previously mentioned, farmers distrust the system and hold a general conservatism towards cash as it allows for immediate payment confirmation (BBC News, 2020., Chatterjee et al., 2020). With this in mind, we decided to integrate our solution with an e-wallet, Paytm, the largest mobile payment platform (Khedekar, 2016). E-wallets ensure electronic transactions can be traced, thus minimizing corruption concerning receiving payments (Khedekar, 2016). Paytm is a popular e-wallet that even merchants in rural parts accept (Pahwa, 2020). It also allows deposits to be sent directly to individuals' bank accounts (Pahwa, 2020). By choosing an e-wallet with a high adoption rate and provides traceable proof of payments, we intend to bolster the farmers' trust in our solution.

To increase farmer autonomy, farmers can determine the prices of their by-products, with price floors or minimum prices protecting suppliers from being undercut. This serves a similar function to that of MSPs by providing suppliers with a minimum price guarantee. In this case, however, this price is set by the market rather than a government institution. Such prices will be calculated using publicly available databases and market research.

Furthermore, buyers must commit upfront a reservation deposit when placing the order. With this partial guarantee, the transaction becomes a binding agreement, which provides farmers with a sense of security of future transaction fulfillment. Also, suppliers and buyers can select each other based on reviews and their own due diligence process. This is all to foster transparency and addres farmers' potential skepticism with using digital applications (Mittal & Mehar, 2012). At the same time, if an order is not fullfilled, the reservation desposit will be returned to the buyer and the transaction voided.

Our solution bypasses the reliance on government financing and enables farmers to sell their stubble and other agricultural by-products directly to buyers that need them and are willing to pay for the materials.

6.3 Designing for Accessibility and Usability

In rural India, illiteracy produces a demographic divide between "social media literate young people (around age 15 to 30) and those above 30" (Wasan & Jain., 2017, p.1). With growing access to low-cost internet devices and increasing mobile and infrastructure development, states like Punjab are seeing an increase in "mobile value-added services (MVAS), money transfers, and access to agricultural information" (Wasan & Jain, 2017, p.2). Though there is increased mobile devices penetration in these populations, few mobile softwares support local languages (Wasan & Jain, 2017). To address this, BuyBy aims to offer a barrier-free user experience by utilizing mobile audio features to read and autofill information and pictorials to minimize text. To further enhance the accessibility of the application, BuyBy uses artificial intelligence, particularly computer vision, to determine crops and by-products through images that individuals upload. These photos can be utilized as product visuals for the marketplace. Essentially, BuyBy enables farmers with all literacy levels to use our app, reflecting the user-centric ideal in our design.

While it would be ideal for a user with any type of mobile phone to use this application, we are designing the initial minimum viable product (MVP) for farmers with smartphones. This is because features like selecting pictures are the best suited on such devices.

To facilitate communication between parties, we've opted to design an in-app communication feature that allows users to send text and/or audio messages. Although messaging applications like Whatsapp and Facebook Messenger are already widely adopted, we cannot use them since they do not offer integration services for free nor stay within the desired application's interface (they direct you to leave the application). Hence, from a cost and user experience standpoint, we've opted for BuyBy to have its communication interface within the application.

6.4 Designing for Infrastructure

In Punjab, barriers that hinder smallholder farmers' access to the mandis include insufficient transportation systems, limited storage facilities, incapacitated roads, and other relevant resources and infrastructures. Additionally, the long traveling distance to markets, high transportation costs, and a lack of timely market information are major barriers preventing farmers from selling their products (Ahmed et al., 2016). Thus, BuyBy will provide buyers with alternative transportation providers as part of the solutions in reducing trade barriers. If a farmer is willing to deliver the products to buyers, one can indicate the distance he or she is willing to travel when inputting selling information. Alternatively, both buyers and sellers can communicate on the preferred method of transportation. Nonetheless, the cost and logistics related to transportation will be the responsibility of the buyers. One of the aforementioned companies, Ninjacart, has adopted a similar business model whereby it arranged the transportation logistics of goods from smallholder farmers to buyers. The success of this strategy is to partner with existing startups with necessary infrastructures to assist farmers in bringing their products to buyers.

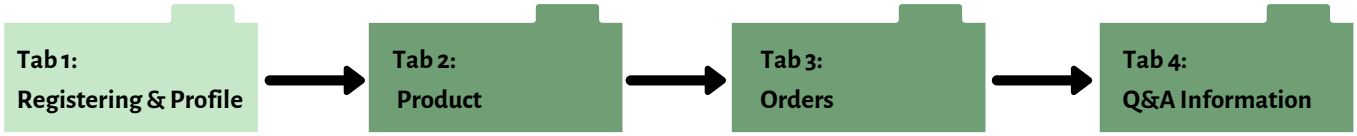
7. The Technology

7.1 Buyby for Farmers Interface

Consider Mr. Singh, a Punjabi farmer. His main crop is wheat, and every year he burns the stubble to prepare for the next harvest quickly. Through his community network, Mr. Singh learned about BuyBy and decided to download the app on his smartphone and try selling his stubble rather than burning it.

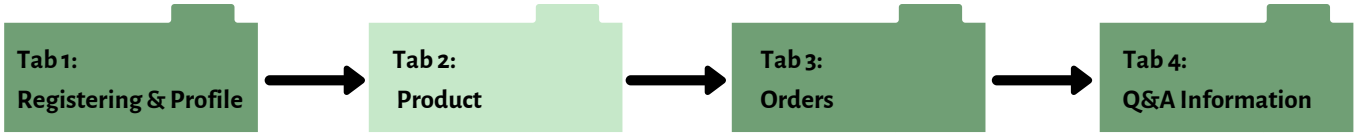
BuyBy

Tab 1: Registering & Profile



Mr. Singh first registers on the app with a login and pin (if available, users can opt-in for face-id login). Once registered, Mr. Singh completes a basic profile by providing information verbally, such as his address (or can use the smartphone's location) and setting up an e-wallet (Paytm account). Since he already has a Paytm account, it automatically integrated with BuyBy with a tap of fingertips. If Mr. Singh ever needs to change his personal information, he can easily navigate to the profile tab at the bottom of the screen.

Tab 2: Product



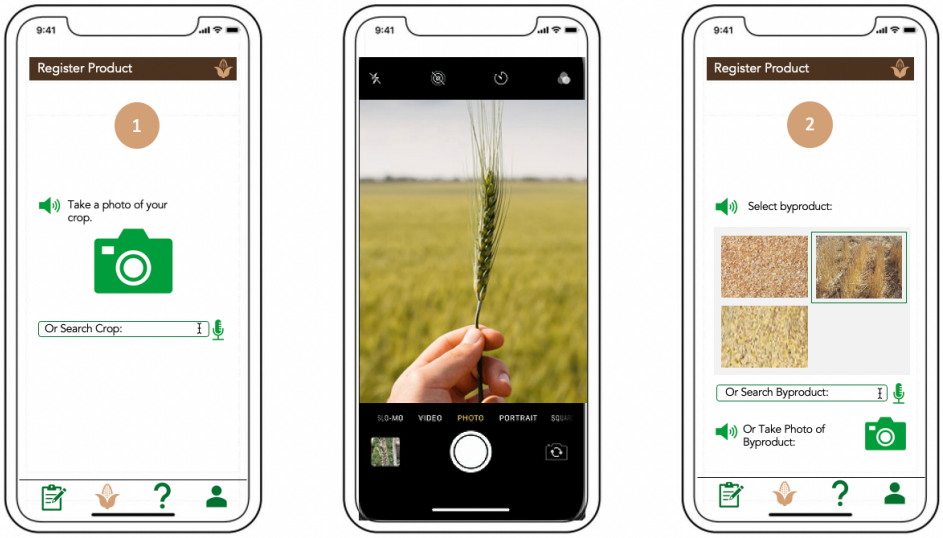
After completed his registration, a new interface appeared. Mr. Singh is looking at the product tab where he can register his by-product for sale. This process begins with Mr. Singh taking a photo of or searching for his crop. On the system backend, BuyBy uses a computer vision algorithm to identify the crop and seek confirmation from Mr. Singh. The crop's potential by-products are then presented to Mr. Singh to select. Mr. Singh can also take a photo of his by-products and let the algorithm identify the type of by-product in the image.

Mr. Singh then fills out the remaining requested information via text, visual, or audio. To ensure ease of use, this information is collected one piece at a time and is presented together for final confirmation.
This information includes:

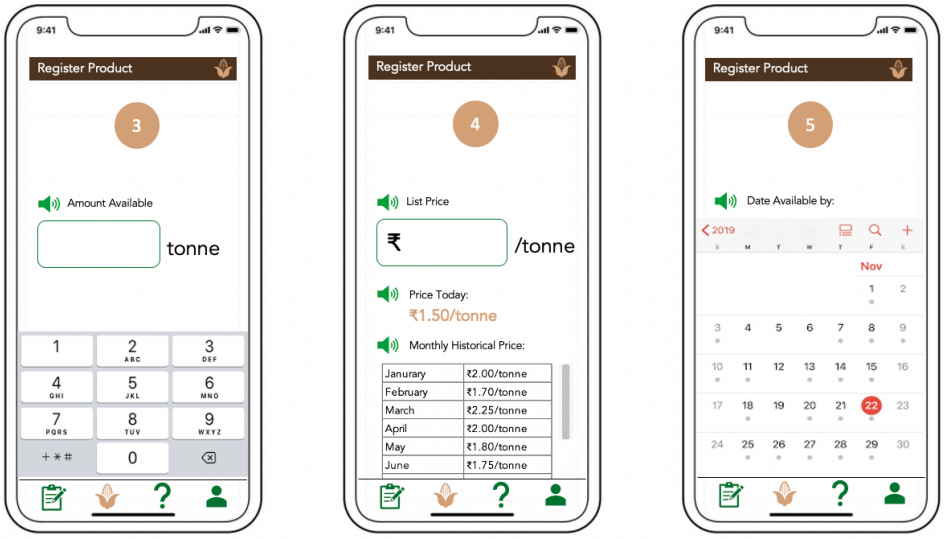
- By-product amount available for sale
- Asking price of by-product (will not allow any number less than the price minimum)
- Estimated availability date
- Binary response for being able to transport goods and if so, to what distance, and
- Potentially uploading images of the goods for sale

When entering the price of his by-product, Mr. Singh will be presented with the by-product's historical and real-time pricing information. This will help him to make an informed decision on what price he wants to set for his goods.

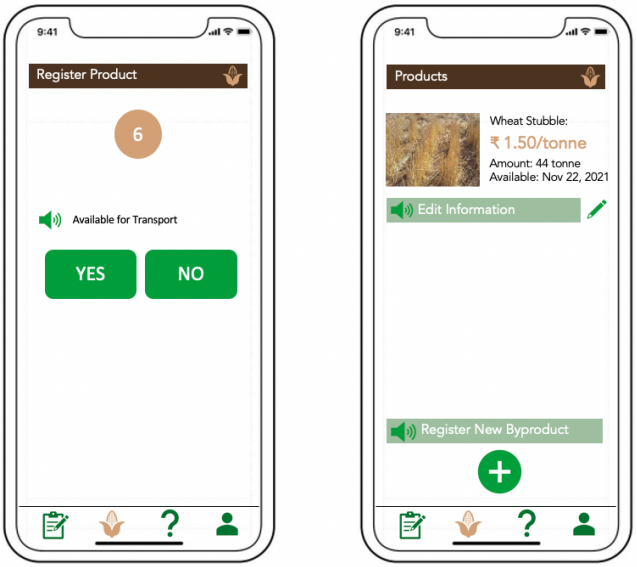
Mr. Singh finally finishes registering his stubble, which now shows up on the "Products" tab. If he wants to, Mr. Singh can repeat the registration steps for multiple by-products and use the "Products" tab to edit their information.



(Fig. 1 BuyBy Photo Upload and Byproduct Identification)



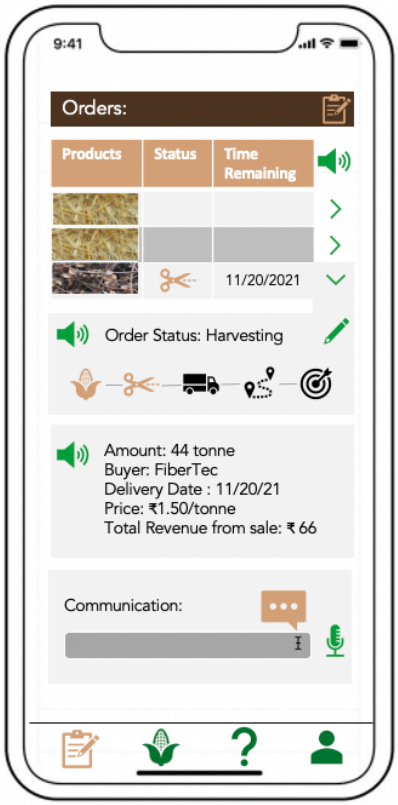
(Fig. 2 BuyBy Byproduct Weight and Availability)



(Fig. 3 BuyBy Transportation and Price Details)

Tab 3: Orders

Tab 1: Registering & Profile → **Tab 2: Product** → **Tab 3: Orders** → **Tab 4: Q&A Information**



(Fig. 4 BuyBy Order Summary Page)

On the third day after Mr. Singh placed his stubble for sale, he receives a notification of an order placement. He goes to the "Orders" tab to view more details, update order status, and communicate with the buyer. For each order, Mr. Singh updates the order status by selecting 1 of 5 options (offered pictorially): "Growing"; "Harvested"; "Ready for Transport"; "In Route"; and "Arrived". Transparency on the "Arrived" stage will depend on whether the buyer selected for the farmer to transport goods or if a third-party transportation service was used. If a buyer selected a third-party transportation service, then it will be the responsibility of the third-party service to update the buyer.

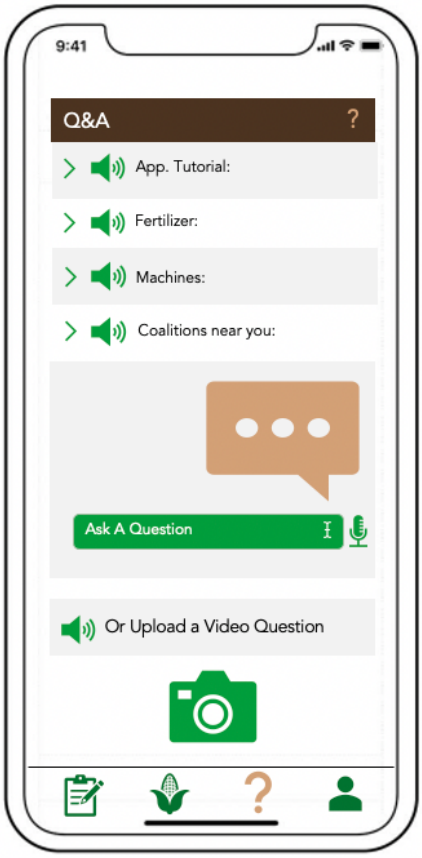
On the "Orders" tab, Mr. Singh can see the total revenue of sales, amount remaining to be paid by buyer, time until order is completed, and any communications that take place between the buyer and supplier. Messages can be listened to or read, and text can be inputted manually or via audio.

Tab 1:
Registering & Profile

Tab 2:
Product

Tab 3:
Orders

Tab 4:
Q&A Information

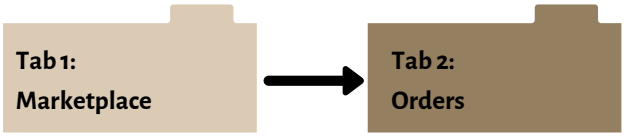


(Fig. 5 BuyBy Q&A Page)

On the Q&A tab, Mr. Singh can search for video tutorials on how to use the application, information about by-products, market and literature solutions to dealing with them and converse with the community of farmers on topics of interest. This tab utilizes video as a medium to educate the importance of sustainable practices when dealing with waste and provides solutions that are currently available for farmers to purchase. Mr. Singh can also ask questions (by uploading a video, audio message, or text) to fellow farmers. This app feature builds a community and support system for farmers.

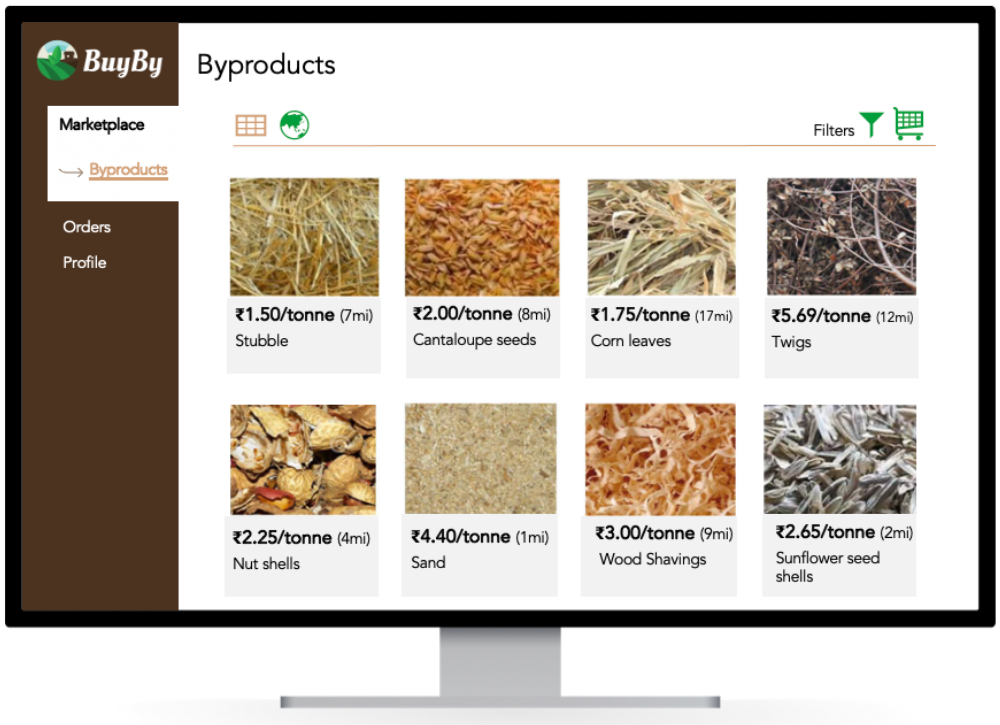
7.2 BuyBy for Buyers

Tab 1: Marketplace



Buyers like the fiber company FiberTec are looking for local stubble suppliers to source fiber for their textile production. Having heard about BuyBy, FiberTec registers its business on the desktop version of the application and fills out a basic business profile. FiberTec then uses the left-hand side menu to navigate to the Marketplace tab. The by-product marketplace centralizes images and information on by-products that currently available on the market. This information can be filtered on:

- By-product type,
- Estimated delivery date,
- Geographic location via a map or address,
- Supplier review, and
- Sorted by price.

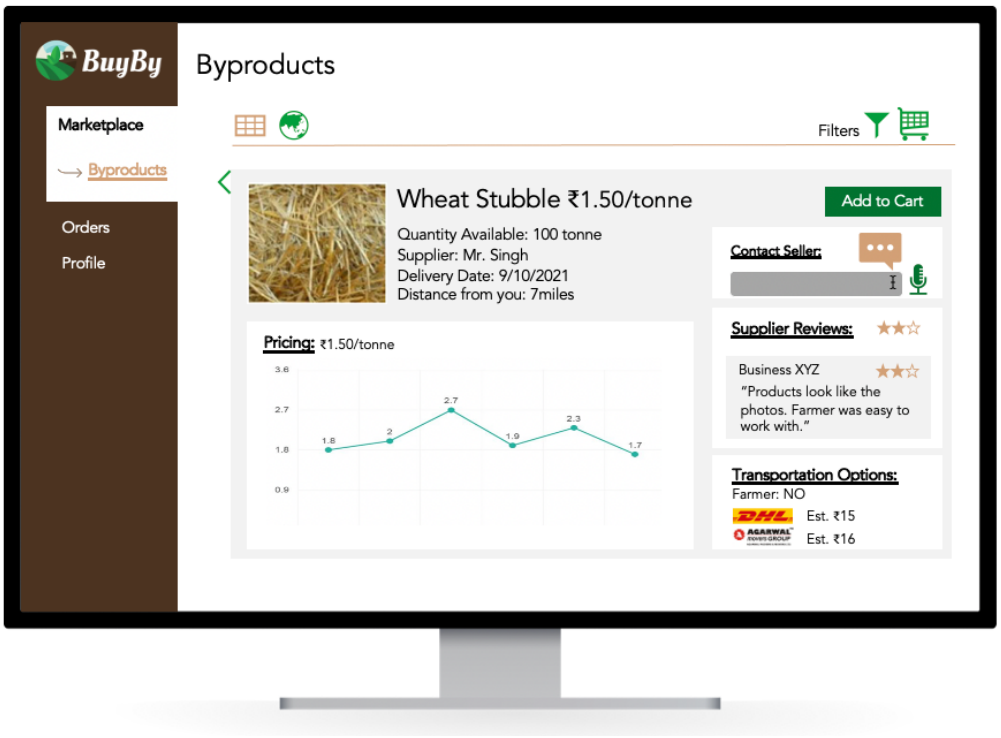


(Fig. 6 BuyBy Buyer Marketplace)

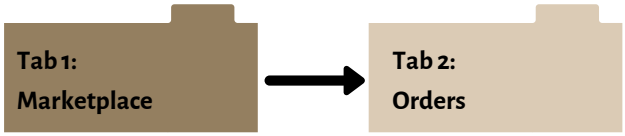
Upon selecting a specific by-product, FiberTec views additional by-product details such as:

- General farm location,
- Quantity available for sale,
- Estimated delivery date,
- Historical and real-time pricing,
- Transportation options (if farmer is available to transport and if not, third party logistic handlers), and
- Transportation quotes

FiberTec can also begin a dialogue with the supplier through the platform to get more information about the stubble. These conversations will be linked to the order when one is placed.



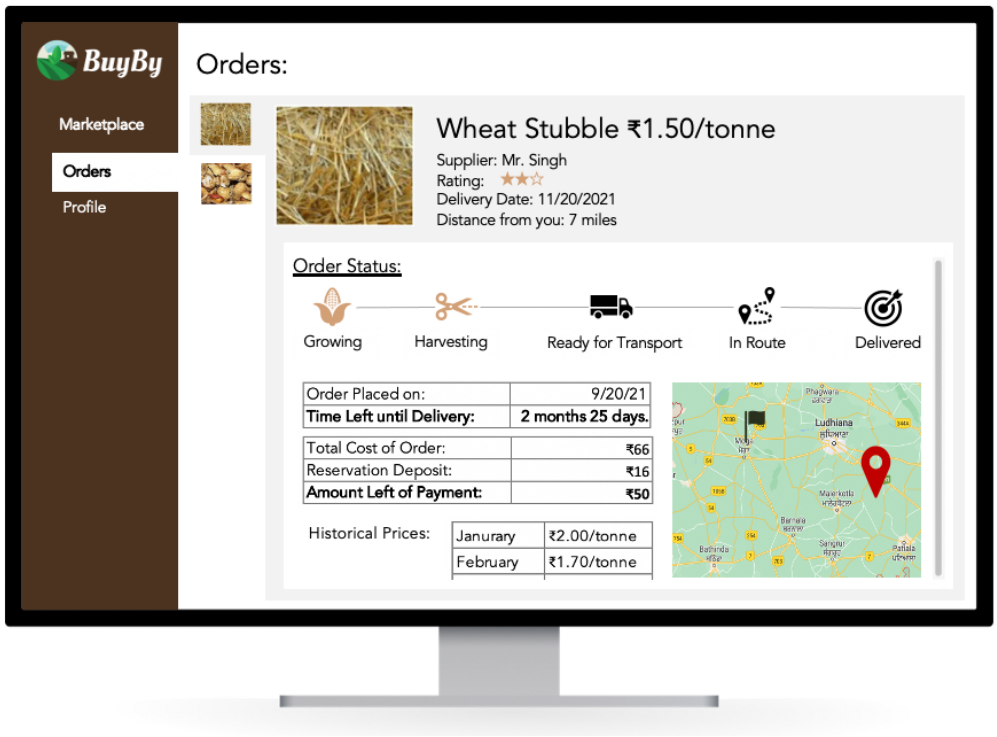
(Fig. 7 BuyBy Buyer Marketplace - Additional Byproduct Information)



FiberTec places an order. To view details on the order, FiberTec navigates to the "Orders" tab. Similar to the famer's view of the "Order" tab, they see:

- Historical and real time item prices,
- Total value of the purchase,
- Amount remaining to be paid,
- Time remaining until order completion,
- Any communications between the buyer and supplier, and
- Order status

FiberTec will only be able to view the status of the order and will not be able to edit that information in any way.



(Fig. 8 BuyBy Buyer Order Detail Page)

8. Backend Description

8.1 Pricing Data Sources

Since the sale of by-products isn't common in India, we plan to use publicly available databases of by-product prices and current Indian crop prices to gauge price minimums. By-product prices are available in publicly available databases like the one provided by University of Missouri (http://agebb.missouri.edu/dairy/byprod/listing.php) and the USDA Economic Research Services (https://www.ers.usda.gov/data-products/feed-grains-database/). India's MSPs (https://farmer.gov.in/mspstatements.aspx) and the National Agriculture Market hold current prices of Indian crops (https://www.enam.gov.in/web/). We believe that this will be a good starting point for farmers to evaluate their by-product's value and supply a price minimum to guarantee a livable wage.

8.2 APIs (application programming interfaces)

An API is a software intermediary that allows applications to communicate with one another and utilize their already-built functions. By leveraging those features and services of existing applications through an API, BuyBy can speed up its development process. As discussed earlier, although there are APIs for popular messaging applications like Whatsapp and Facebook Messenger, they are not free and direct users to leave the BuyBy application in order to use them. Hence, in the case when an API cannot be used, we would have to develop the necessary functions. In BuyBy, all map features will be using APIs from tools like ESRI or Google Maps. Transactions will be done using an API with the E-wallet, Paytm.

BuyBy will also use an API with an application that uses computer vision to identify crops. Computer vision works by commanding devices to send images to an algorithm that evaluates and extracts an output, which in our case classifies the type of crop in the image (Toth et al., 2020). Academic studies that have developed computer vision for agriculture with publicly available tools and datasets (open source) have achieved 93% accuracy in crop classification (Toth et al., 2020). Companies working to commercialize this technology are likely to be even more accurate since they typically collect their own high-quality datasets, which improves the algorithm's accuracy (Dodge & Karam, 2016). Firms like Anolytics are already doing such work for crop sorting. Therefore, it will be beneficial to establish partnerships with these companies to technology giants like Amazon with computer vision capacities in developing this aspect of our solution.

9. Intended Benefits and Outcomes

9.1 Alleviating Delhi's Air Pollution Crisis

Burning of by-products such as stubble can make up 40% of the Delhi's prominent air pollution problem, with the average contribution increasing from 10 to 15% in recent years, driven particularly by stubble burning in the Punjab region (source Environment Ministry India et al., 2020; Greenpeace SEA et al., 2020).

BuyBy provides a platform that allows farmers to sell their by-products. It offers an economically viable alternative to burning by-products, thereby reducing air pollution. If BuyBy can reduce stubble burning in the region, it could contribute to saving some of the over 50,000 people that that die each year from air pollution in Delhi (Environment Ministry India et al., 2020; Greenpeace SEA et al., 2020). Given the significance of its potential impact, it is critical to be able to measure BuyBy's progress using metrics like annual acreage burned or not burned, air quality index metric, etc. Scaling BuyBy further could not only save even more lives, but drastically improve the quality of life of India's citizens. Thereby, BuyBy ensures healthy lives and promotes well-being for all (SDG 3: Good Health & Well-being). We can track our progress by measuring the reduction of stubble burned and the expected, as well as the real, increase in air quality.

9.2 Supporting Farmers in Economic Crisis

Some farmers have been forced to sell off portions of their landholdings due to increased debt and reduced productivity (Rai, 2020). The diminishing of land holding threatens the future livelihood of farmers. Moreover, the burning of by-products has scorched the organic content of the soil up to 12 cm deep, decreasing long-term fertility and increasing the need for fertilizer, further driving up costs.

BuyBy tackles both issues by providing farmers with an additional source of income without the need to buy more land or repurpose existing land. In this unregulated market, farmers can sell by-products without quotas or government intervention. Since the by-products are already there, selling them is a low-barrier and economic way to increase the income of farmers. Metrics that we can use to measure farmer wellbeing include revenue farmers generate through BuyBy, number of farms participating in the BuyBy marketplace, product quantity available over time, etc. The reduction of stubble-burning further alleviates decreasing fertility and need for fertilizer, which can be measured using soil quality metrics and resource usage. Thereby, BuyBy ensures sustainable consumption and production patterns (SDG 12: Responsible Consumption & Production) and protects farmers from slipping into poverty (SDG 1: No Poverty). We quantify our impact on this crisis through income generated per farmer: Since byproducts typically go to waste, every Rupee farmers earn through BuyBy helps farmers to secure their existence.

9.3 Tackling the Global Climate Crisis

Burning of by-products is a significant driver of climate change (Levine et al., 1995). Stubble burning alone constitutes more than one third of the global emissions from biomass burning (Levine et al., 1995). Using by-products instead of burning or disposing of them, i.e. as a replacement for coal or fabric, can help facilitate sustainability and reduce the carbon footprint, particularly in countries that are currently struggling to reach climate goals. Since every byproduct burned or rotten creates greenhouse gases, we will track our progress for tackling climate change by the amount of CO_2 saved through BuyBy.

10. Feasibility and Implementation

To make the product a success, we must ensure the feasibility of all implementation steps throughout it. Satisfying stakeholder expectations, understanding their motivation, and making sure that they are satisfied with the product is vital to scale BuyBy and help farmers. Another aspect is our go-to-market and implementation strategy. A marketplace can only succeed if there is enough supply and demand to find a match. In this section, we will elaborate on these facets of BuyBy.

10.1 Stakeholders

The following table lists our key stakeholders and describes their role in the process.

Stakeholder	Role	Benefit	How to engage them
Sellers: Farmers	Sells by-products on the marketplace	• Use by-products as a source of income • Education materials	Marketing / Advertising Cold-calling, industry fairs, associations
Buyers: Biofuel companies (I.e. Fortum), **Textile mills** (I.e. Altmat)	Buys by-products on the marketplace and uses them for fuel generation, textile production, etc.	• Source by-products for fuel, textile production • Fair, affordable, and flexible solution without a middleman	Targeted advertising Engaging local community leaders and employees to visit farmers and promote the platform. Use FPOs (see below).
Transporters: Either farmer, our employees, or third-party	Transports goods from the farmers to the buyers.	• Flexible and fast compensation	Start with employees Engage farmers and "gig-workers" through outreach

Additionally, on-the-ground support and partnerships are crucial in facilitating product adoption and assisting farmers in learning how to use the app. They are not directly involved in the marketplace operations. These participants are insitutions, organizations, individuals, and farmer network.

Partners	Role	Benefit
On-the-ground Enablers: Employees, Local community leaders, Educational institution	Serve as sources of knowledge, support farmers in the process, and spread the word.	• Salary / Commission • Opportunity to grow and gain experience
Farmer Producer Organizations (FPOs)	Connect and grow through the platform, serve as experts	• Opportunity to get new members • Increase outcome for their members through by-product monetization.
Government and Local Authorities	Used to buy crops from farmers, now primarily lawmaker	• reduced crop-burning without need to compensate farmers. • Aligns with current policy to liberate the market, e.g. the farm bill

10.2 Product Implementation Strategy

Further discussions with more stakeholders are necessary to refine our value proposition, product, and pricing model. Based on this initial feedback, we will build a minimum viable product (MVP) with an interface where farmers can offer their by-products. This MVP is then provided to our partners who will conduct outreach to develop our marketplace network.

In this MVP, we facilitate buying and pick up crops. On the buyside, we will set up a virtual marketplace and deliver to buyers based on initial contracts with farmers. This enables us to test our product in real life without needing to run expensive campaigns to get people on the platform. After an initial campaign to attract farmers and buyers in a small pilot region, we will launch the marketplace. Gradually, we will then introduce more features such as transporters, and ultimately scale the product throughout the Punjab region.

The rest of India has adopted farm bill reforms which encourage inter-state trading, e-trading, contract farming and direct marketing. BuyBy is an opportunity to introduce a low risk free market solution to Punjab (Kriti, 2020). BuyBy is positioned so that if the region decides to adopt the farm bill reforms, farmers will have familiarity with and trust in the BuyBy marketplace to sell by-products and diversified agricultural products.

Task	Q3 21	Q4 21	Q1 22	Q2 22	Q3 22	Q4 22	H1 23	H2 23	H1 24	H2 24
Conduct additional stakeholder interviews										
Prototype development: Minimum Viable Product										
Campaign to attract farmers and buyers in pilot region										
Launch of marketplace										
Introduction of Transporters										
Scaling across the entire Punjabi region										

10.3 Project Funding

We plan to fund the initial planning and prototype development through external grants and donations. As soon as we develop a functional marketplace and launch it in Punjab, we can start tapping into internal revenue potential for the value we provide to fund operational costs and salaries. Once we reach critical mass, we will be able to sustain the platform without additional external funding.

Starting from 2023, we plan to fund ourselves through a small service fee for every transaction run through our platform. Unfortunately, this is necessary to sustain our offering and grow our user-base further. Alternatively, we could fund BuyBy with a long-term grant and continue to offer a free service to farmers and buyers.

11. Future Vision and Conclusion

Globally, the issue of stubble burning extends to 2000 Mt every year (Devi et al., 2017). While farmers in India and China burn large a large share of this contingent (Chawala & Sandhu, 2020), the issue persists even in developed countries with advanced farming techniques, such as Australia and Canada (CBS, 2007; Scott, 2010). This illustrates the possibility to expand BuyBy beyond Punjab and India to other, diverse markets. Although the social dynamics, as well as the individual agricultural products, are unique in any region, the platform was designed to address the underlying socioeconomic issues that are inherent to the problem of stubble burning itself and provide incentives for behavior change to farmers. Moreover, ByBuy is well-positioned to capitalize on future policies that prohibit the burning of stubble and to further drive a future market of by-products. It will help facilitate the spread of alternative management practices by allowing farmers to benefit financially from a growing market.

As a platform solution, BuyBy can be easily adapted to novel or regionally specific agricultural by-products, making it highly suitable for different locations. Due to its little reliance on a pre-existing infrastructure, it can be easily implemented in rural and developing areas, and serve as an additional stream of revenue for farmers, while avoiding waste and negative impacts on the environment.

In the long term, we hope to see global stubble burning rates, and therefore associated issues, such as air pollution, nutrient loss, and greenhouse gas emissions, decrease significantly. BuyBy will help farmers to move beyond the status quo and advance agriculture toward good health and well-being, zero hunger, climate action, and sustainable life on land.

12. Appendix

Stakeholders Interview - Needs Assessment

Name	Role	Needs Identified
Roshan Rathod	Gender Specialist for Natural Resources Management	• Gender inequality in land owning exists due to titles granted to males. • Just and fair prices are needed. Farmers do not have control over pricing and MSPs are being lost partly due to middlemen and per hectare yields being lacking. • The economy is largely cash based and the transactions on an online platform must be reliable, easy to use, and quick. • Larger buyers with capital and infrastructure can set fair prices.
Arasdeep Singh	Smallholder Farmer Activist	• Money management structures such as arthiyas and APMCs that control prices are severely lacking. • Almost all farmers have internet access but need training in order to use platforms or an easily understandable platform. • Long distance transportation of crops can be a limiting factor for small shareholder farmers. • The new laws have removed the government from originally connecting farmers to international markets and now corporations have taken over the role.
Suman Chandra	Yale School of Forestry and the Environment, Master of Environmental Management Student	• Platforms or mobile solutions are limited by farmer illiteracy. • An assured income level is vital to a solution. • Constraints to diversifying to other crops are lack of procurement which was once fulfilled by the government and now transitioning out, forward market linkages, and technical know-how.
Sakshi Balani	Team Lead, Air Pollution Action Group	• Air pollution from stubble burning has received a lot of attention, but soil health is also degrading due to stubble burning. • Most farmers are tenant or sharecropped hired by larger landholders which precludes them from financing and subsidies that encourage regenerative agriculture and long-term soil health management. • The Minimum Support Price incentivizes farmers to grow paddy and wheat so diversifying to other crops. • Logistical and transportation infrastructure were provided by the government prior to the farm bill and farmers will now have establish infrastructure and cold chains themselves to get products to market. • Small farmers need access to economies to scale in order to grow products not supported by the MSP.

Gopal Singh	Punjab Farmer	• Small and marginal farmers in Punjab and all of India face similar problems of rising debt, a depleting water table, lack of a transparent and competitive market system, and swings in market prices for perishable produce, and a slow diversification to other cash crops. • The largest problem farmers face is marketing as Punjab has its own APMC Act to regulate the sale and purchase of agricultural produce in the state. • Only a few commodities are permitted to be privately traded outside APMC mandis while the major Punjab crops (paddy and wheat) are traded only in APMCs. • Due to minimum price supports (MSPs), farmers are not incentivized to diversify to high value items such as fruits and vegetables without MSPs. • Current use of agricultural by-products is limited despite proactive efforts by the government.

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