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USA, Food storage against unexpected weather

Harvest Loss Prevention Using On-site Storage

It is estimated that one in nine people suffer from hunger— according to the 2020 Global Nutrition Report— and that malnutrition is still the leading cause of death in the world ("Global Nutrition Report", 2020). However, this percentage varies between countries. For example, 14.5% of people in India are malnourished: around 200 million people ("Hunger in India", 2020). These numbers have only increased in response to the ongoing coronavirus pandemic. Because of the financial crises COVID-19 has caused, the World Bank estimates that "40 to 60 million more people will be living in extreme poverty in coming months, depending on the scale of economic shock" (Pangestu, 2020). Even in the US, a developed country, 30-40% of Americans currently face food insecurity.

While there are many factors that contribute to hunger, including poverty and civil unrest, food waste and distribution continues to be a major problem. The world produces more than enough food to feed the entire population and wastes enough food to feed the world's hungry twice over ("Why Is World Hunger Still A Problem?", 2020). During the current Covid-19 pandemic, farmers do not have any consumers to buy their harvested crops, and restaurants are serving food to too few consumers (Kaufman, 2020). This has led to even more food waste. Even before this pandemic, one-third of all food produced was being wasted ("Worldwide Food Waste", 2020). Food waste can be mitigated through changes in lifestyle and spreading awareness, but also by resolving the persistent lack of food storage in underdeveloped countries.

India is a country of 1.35 billion people in Asia ("World Bank", 2020). Most of the population — 66% — is rural. It is a parliamentary democracy with a federal system of government. 52.8% of the land is arable ("The World Factbook: India", 2018). Rice, wheat, oilseed, cotton, jute, and tea are the most important crops. Agriculture is 15% of the GDP but is the occupation of 47% of the workforce. Rice, spices, sugar, cotton, and castor oil are the major agricultural exports ("Economic Survey", 2020). The average farm is small at about 1 hectare (2.5 acres), whereas, it is 444 acres in the United States (Kassel, 2020). The climate is tropical with summer monsoons that deliver most of the precipitation throughout the country. The country is vast with a very diverse geography from the world's tallest mountains — the Himalayas; desert in the North-West of the country; plateau in the Southern peninsula; and extensive agricultural plains in the basins of the Ganges, Indus, and Brahmaputra rivers. In addition, several other major and minor rivers irrigate arable land throughout the country.

A typical family in India is engaged in farming as it provides livelihood for nearly half the population (“Economic Survey”, 2020). They are either small farmers or landless farm laborers. Families in rural areas, just as in urban areas, have two children but often live in multi-generational households. Houses are constructed out of fired bricks or mud and thatch in rural areas. Rice, wheat, and maize are the main staple food. These are eaten along with pulses and dairy products. Most of the population eats meat but the level of consumption is low (Ritchie, 2019). Cooking is traditionally done using wood fired stoves in rural areas. However, liquefied petroleum gas (LPG) is increasingly used as a cleaner alternative (Koshy, 2019). The average wage is Rs. 384 (5 US dollars) per day but it is half that in rural areas (“India Wage Report”, 2018).

Farming, especially in India, is very dependent on seasonal weather. Different crops are sowed and harvested at different seasons of the year. In India, there are two broad groups of crops adhering to different climatic conditions and seasons. These are the Kharif crops and Rabi crops (“Kharif Crops vs Rabi Crops”, 2018). The Kharif crops are sown at the beginning of monsoon season: a period of heavy rainfall and humid climate in the summer months (Stanley, 2020). This season spans from about June to October however the exact timing varies on the region and arrival of rains. The main Kharif crops include paddy, maize, jowar, bajra, cotton, sugarcane, groundnut, and pulses (“Kharif Crops vs Rabi Crops”, 2018).

Rabi crops — including wheat, gram, peas, and barley — are grown in the winter season. They are sown at around October and then harvested in the spring (“Kharif Crops vs Rabi Crops”, 2018). Since they are grown in a relatively dry season, they are not directly dependent on rainfall like Kharif crops. However, unseasonal rains can cause great damage on very important crops. For example, farmers in the Warangal, Mahabubabad, and Mulugu districts suffered heavy losses due to unseasonal rains damaging paddy, chili pepper, and maize crops in April of 2020 (“Unseasonal Rains”, 2020). The harvested grain was set out to dry and got damaged. Farmers were already in a critical financial state because of the lockdown measures due to COVID-19. These sudden rains have caused farmers to lose a whole year’s worth of crops. The main problem farmers had was no way to shield their crops.

Recently near Delhi, rains damaged mature crops including wheat, potato, chickpea, and rapeseed (Bhardwaj, 2020). In the state of Bihar, several Rabi crops such as mustard and wheat were also damaged due to sudden rains (Khan, 2020). By the time the farmers get any compensation from the government, it will be too late for their next season. Even farmers who managed to save their crops will find it difficult to sell for reasonable prices. There are many other such events that go unreported. Even farmers who are not affected by unseasonal weather often do not find buyers to sell their crops to in a timely manner, which ultimately leads to financial problems and further food waste.

The government of India buys a large fraction of the farm output by providing a minimum support price to farmers. The government also runs a public distribution system to provide subsidized food grains to the population. Because of bumper harvests in recent years, the market prices of food grains are often low, resulting in the government buying an exceptionally large portion of the crop. Because of this, they need a large and varying number of storage facilities. The existing warehouses, called godowns, are often not sufficient, in which case the harvest is stored in areas that are not properly protected. A substantial chunk of the crop is lost due to rot in these makeshift facilities.

In addition, it takes time for the farmers' crops to be bought by the government and then transported to the storage facilities. During this period, unseasonal and extreme weather can damage already harvested crops. With no storage facility on small farms, produce is often left on the road and spoils.

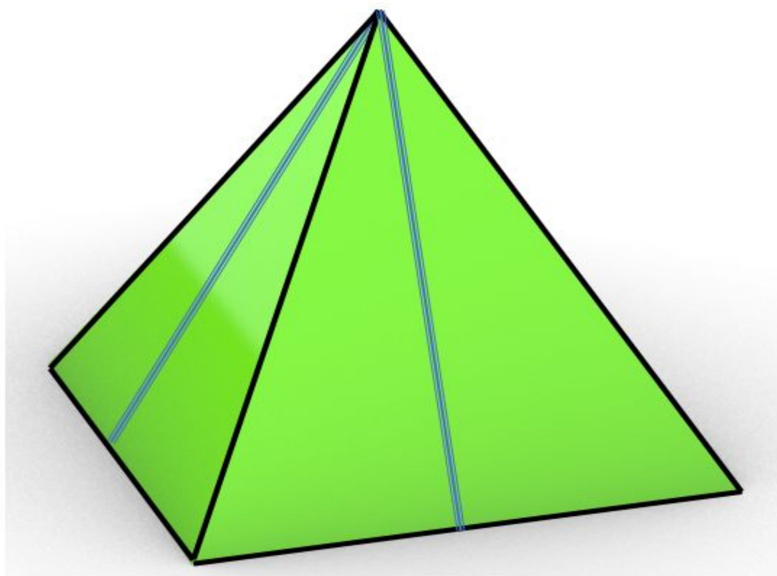
Food insecurity is pervasive throughout the country. Both rural and urban areas in India have segments of the population that are suffering from food shortages. Food shortages have a disproportionate effect on the most vulnerable sections of society. 38% of the population is affected by malnutrition ("Malnutrition in Children", 2020). Women and children are often undernourished. This has significant impact on maternal health. Low birth weight and stunting of children under 5 is caused by inadequate nutrition.

These issues must be resolved by creating a temporary food storage system for small farms. This would prevent crops from being damaged due to unseasonal rains and provide a preliminary shelter for the harvest before the government buys the produce. In addition, the systems could plausibly double as small government storage centers, which would improve food distribution overall and therefore reduce hunger.

This paper proposes original solutions to this problem of temporary storage of harvested crops. It is proposed that "Harvest Pods" be developed to enable distributed storage of crops. These pods would take the basic form of a cheap but durable structure.

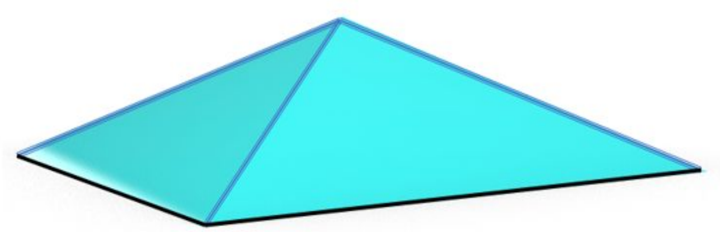
Many camping tents already on the market are waterproof and provide shelter from rain and other extreme weather. The same material could be used to develop harvest pods for small farmers to store their harvested grains. Furthermore, the material would be enhanced to provide protection against rodents and other pests. The pod designs are now presented followed by an analysis of the production costs.

The first proposed solution would be to create small, reasonably priced pods for all small farms in India. These pods could be used to store already harvested grain and protect them from unseasonal rains. To be effective, the pods should cover the bottom, top, and all sides. This would prevent crops from being damaged by extreme weather and provide temporary storage before the crops are purchased. While this solution would solve problems of unexpected weather and storage before the government, it has its limitations. For one, when it just begins to rain, farmers would have to physically close the pods in case of inclement weather. This is a relatively minor problem however, because farmers can notice signs that rain is coming such as an overcast day or daily weather reports. Even if these rains were not part of the wet monsoon season, it is enough if the farmers know that rain is likely. The closed pods would provide adequate protection.

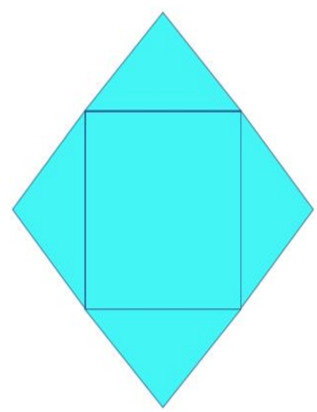


Solution 1: Multiple harvest pods (tents)

The second solution provides harvest pods that can be opened and closed in a petal design to allow sun drying and ability to secure from all sides when necessary. This pod design has a pyramidal shape. The pod opens when unzipped from the corners and forms a rectangular or square surface to spread the harvest for sun drying. In case of bad weather, the pods could be zipped up from all corners and closed off. This design does not require moving the crop physically to a new location for drying.

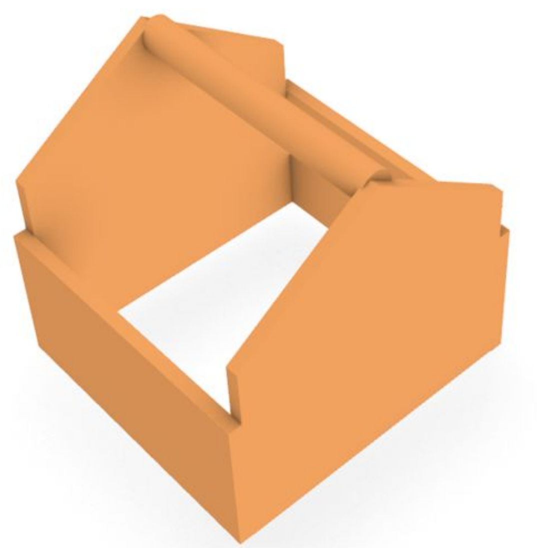


Solution 2: Petal opening harvest pods

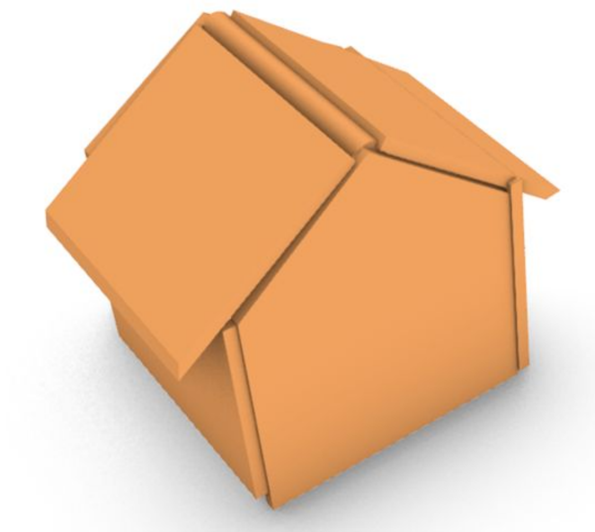


Solution 2: Petal opening harvest pods (Net diagram)

The third proposed solution is an automated harvest pod. This would be structured in the shape of a sloped roof shed, but with a longer base. The base is shaped like a rectangle but without a covering on top. This is where the harvested crops will be laid. Then, there will be a retractable roof that will be activated automatically whenever it rains. The retraction mechanism will be made with easily available parts such as Arduino, and commonly available motors and rollers. The base of the pod is also made of the same material as the sides for protection from below. The sides can be manually rolled up, just as in the previous designs. This solution would be a bit more expensive but easier for larger farms. Cost of electrical and electronic components are very low these days and this will be utilized to make this solution cost-effective. This third design would allow farmers to sun-dry and protect their grains from unexpected weather onsite. In addition, this automated solution will help farmers who have multiple harvest pods on different plots of land to simultaneously close their pods.



Solution 3: Automatic roof harvest pod (roof hasn't activated, in center roll)



Solution 3: Automatic roof harvest pod (with roof)

The harvest pods proposed in this paper shall be made out of easily available but durable materials for reuse over several seasons. An outer stainless-steel mesh will prevent rodents and other larger pests from entering the pod. The stainless-steel mesh of Standard Wire Gauge of 20 (about one millimeter) with a hole size of three to four millimeters would be necessary for rodent protection. This would need about two and a half kilograms of stainless-steel per square meter. For production in bulk, assuming a typical price of about two dollars for a kilogram, and a fifty percent additional cost to produce the mesh, the price per square meter of the outer mesh would be eight US dollars. The inside of the pod would be made of the Purdue Improved Crop Storage (PICS) technology or similar materials (Baributsa et al., 2013). PICS uses two polyethylene liners and one outer layer of woven polypropylene. The cost of material for PICS is one US dollar per square meter.

The total cost of the protective layers of the pods would thus be about nine US dollars. For a four-meter-wide and four-meter-long pod with a side height of two meters the surfaces would cost five hundred and seventy-six dollars. Structural supports on all corners and the retractable roof mechanism would take the cost to about six hundred and fifty US dollars. With the pod filled with rice paddy up to half its height, sixteen square meters of grain could be held. With a density of five hundred kilograms per cubic meter and a typical Indian government support price of twenty-five US dollars per hundred kilograms, two thousand US dollars' worth of grain could be held in a pod of this size.

If the useful life of the pod is assumed to be five years, the amortization period can be taken to be the same. Assuming an interest rate of five percent, the annual cost of the pod would be one hundred and fifty US dollars. If these reduced the current level harvest losses of thirty percent by one-half, the average savings would be three hundred dollars. Thus, even with these conservative numbers, these pods would easily pay for themselves just from waste prevention. Just saving half of the twenty-three million tons of the food grains wasted in India ("Worldwide Food Waste", 2020), the net savings would be more than two and a half billion US dollars. The additional benefits of a spatially and temporally distributed storage system would make the advantages even greater for farmers, the market, and the government.

Any one of these harvest pod solutions would provide farmers with the ability to store their harvest temporarily. They will be able to take their crop to the market or to the government facilities undamaged and at the proper time. The farmers will also be able to avoid having to sell the crop right away after the harvest when the prices are low. They will be able to ride out market fluctuations and sell at the right time.

The government storage facilities will also be able to spread out their purchases so that they do not exceed their capacity. A larger fraction of the food grains going to the open market will reduce the amount that the government must purchase. This will lead to less food waste, while benefiting farmers, the government, the open market, and the public distribution system. Food availability will increase throughout the country and throughout the year. This will lead to less hunger and better nutrition for the whole population. These solutions are applicable to several countries and crops throughout the world.

These solutions are flexible so that the government, international organizations (such as the World Bank, the Food and Agriculture Organization of the United Nations), and private charitable foundations, can design projects to provide such storage mechanisms across the country. If the initial development is funded through grants, the production and sale of these solutions could be a self-sustaining market. Large scale solutions are difficult to implement in India because of the fragmented nature of the society. The solutions proposed in this paper are of a distributed and small-scale nature that will be more readily accepted and scaled up.

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