Developing a Collaborative Process for the Application of Appropriate Technology on Farms in Mandi District

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ABSTRACT

Agriculture is the primary occupation in Himachal Pradesh, yet farming implements have not modernized alongside national trends. Indian Institute of Technology Mandi (IIT Mandi) students have been developing prototypes that can alleviate regional cultivation challenges. Our project documented existing agricultural practices, challenges, and perspectives on technology in order to develop a collaborative process for students to design devices that suit local needs. We tested our appropriate technology rubric to develop a seed planter and irrigation system for terraced farms.

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AUTHORSHIP PAGE

The introduction, background, and methodology were drafted as a combined effort between Cody, Samantha, and Amanda. Cody took primary command of revising the introduction and background as well producing standardized forms for recording interview data and planning itineraries for fieldwork. He produced the computer aided design (CAD) models of both the corn seed planter and irrigation system. He, Sakshama, and Prashant assembled the seed planter. Cody and Samantha were the primary composers of the Appropriate Technology Rubric. Samantha drafted and refined the results, discussion, and project outcomes sections, produced the team informational graphics, and assembled the final paper. Samantha and Amanda were responsible for organizing our transcribed responses into an Excel data sheet. Amanda developed the tool catalogue, weekly PowerPoint presentations, and served as team graphic designer.

Prashant and Sakshama provided input on important concepts and cultural nuances to the paper sections. They assisted in identifying stakeholder sites, itineraries, as well as revising the methodological questionnaires. They directly communicated with farmers and served as scribes and translators of the data gathered from each interview.

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Executive Summary

Collaborating with Local Farmers to Improve Agricultural Practices

The last five decades have seen tremendous growth in farming capacity in India, providing the country agricultural independence (Department of Agriculture and Cooperation, 2012). The farmers of Mandi District, Himachal Pradesh, rely heavily on local agriculture, despite the hilly terrain. They produce crops for both commercial and subsistence purposes, commonly cultivating wheat, maize, potatoes, and rice, as well as other staple fruits and vegetables (Heitzman, 1995). Recognizing a regional need for innovation in suitable agricultural technology, the Indian Institute of Technology Mandi (IIT Mandi) is developing prototypes that can alleviate challenges in cultivation and harvesting processes in the region. Such technologies could increase productivity and profitability for local farms (Figure 1).

Figure 1. Farming in Mandi District requires unique technology, independent of the large scale farming machinery that operates on large, flat farms.

Modernization in agriculture, however, has often led to standardized, general-purpose technologies. Standard equipment and machinery, useful for some farms, does not match the diverse needs of local landowners.Government-endorsed farming technologies such as large tractors and mechanical farm equipment, are often designed for large-scale, flat farmlands. The terraced or small-scale farms of Himachal Pradesh are excluded from the design process, resulting in environmentally incompatible machinery. Furthermore, experts recommending or designing these devices sometimes fail to address that farmers may lack experience with the use, maintenance, and the long-term costs that come with complex innovations (Stone, 2014). Farmers should be included in the design of agricultural technologies that suit their local needs. Such collaboration could mitigate the alienation of the grower from the designer, resulting in more relevant, feasible innovations.

This team collaborated with farmers in a region surrounding Mandi Town to identify appropriate design innovations that might improve local agricultural practices. To accomplish this, we addressed four primary objectives. First, the team documented current practices and technologies used by local farmers. Second, we evaluated farmer perceptions of new agricultural innovations, with regard to their existing challenges. Third, the group developed a rubric to guide the design process for appropriate agricultural technologies. Fourth, we developed appropriate innovations to address the farmers' greatest challenges. The team also provided suggestions for additional opportunities for development. Special attention was given to a technology assessment of recent IIT prototypes in small village settings.

THE NEED IN MANDI DISTRICT FOR APPROPRIATE AGRICULTURAL TECHNOLOGY

To design the most relevant tool for local farmers, our team adopted criteria for *appropriate technology*, an approach to engineering that establishes design criteria to "enhance human fulfillment through satisfaction of human needs" (Hazeltine, 2003). Theorists of appropriate technology insist innovations should be appropriate to the economic and cultural setting of the user. This movement originated in response to U.S. President Harry S. Truman's Four Point Plan in 1949, a technology-heavy aid program for developing nations (Pursell, 1993). Engineers implementing Truman's Plan followed a heavily western bias toward industrialization. The result was the construction of complex infrastructure that often fell into disuse. Theorists generally agree on a set of core principles for appropriate technology, which we have synthesized in Figure 2, with farming in mind.

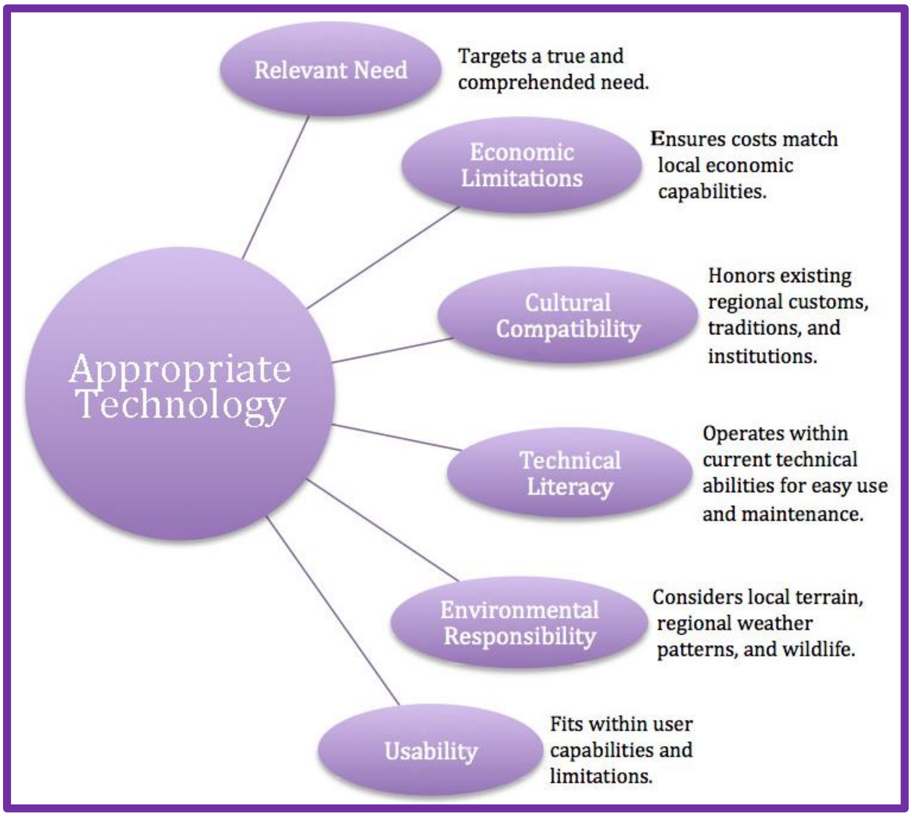

Figure 2. The six dimensions of appropriate technology. Adapted from Pursell, 1993; Hazeltine, 2003.

In 1973, economist E. F. Schumacher published *Small is Beautiful: Economics as If People Mattered*. He advocated for the development of "intermediate technology". The tools provided should be cheap and relatively simple to use and maintain by local users; only these technologies would be considered "appropriate" (Pursell, 1993).

The application of appropriate technology to the region around Mandi requires understanding the local context of agriculture. In the 1960's, the Indian government committed to feeding its expanding population without extensive reliance on imports, consequently pushing to improve the efficiency of Indian farmers. This "Green Revolution" emphasized improvement of agricultural technology to increase the output and transportation of goods. Since then, India has dramatically increased output through improved cropping methods, seed distribution, and agricultural machinery. This has allowed the country to expand its gross output of agricultural products without greatly increasing the total amount of cultivated land (Department of Agriculture and Cooperation, 2012).

Many farmers in the southern and central regions have followed government suggestions and adopted modern farming machinery, including tractors, automated seed planters, and combine harvesters (Department of Agriculture and Cooperation, 2012). This strategy has yielded mixed results, though. While the methods dramatically have increased farming output in central India, this type of machinery is not as suitable for small farms in the topographically-challenging landscapes of Himachal Pradesh (Department of Agriculture and Cooperation, 2012).

The majority of farmers in Mandi District operate terraced farms, cultivating step-like outcrops carved from the sloped hills dominating local landscape. The locations of these terraces can range from steep, formidable hillsides to more hospitable valley floors (Figure 3). There is no standard shape, height, or width for an average terrace as each depends on the terrain, tools, and the specific farmer who originally created the terraces. Terraced land is traditionally passed down through a family, with the same land available for use across several generations. Farming on such terraces involves primarily manual labor with a variety of traditional tools.

Figure 3. Terraced, mountainous terrain dominates much of the region surrounding Mandi Town.

Small farms in Himachal Pradesh, specifically in Mandi District, can be put at an increased risk if an inappropriate technology is adopted. Many of the innovations developed for the rest of India are inefficient in this region. For instance, less than 10% of the land is suitable for agriculture, yet the majority of the population is employed in this sector (Heitzman, 1995). As of the 2011 census, Mandi District's population was 94% rural. The majority of these citizens subsist on the cultivation of less than one hectare of mountainous land (Mandi District: Census 2011 Data, 2011; Vaidya, 2006).

In 2013, university researchers H.R. Sharma and S.K. Chauhan conducted a study on habits of technology adoptation and challenges in Himachal Pradesh to identify overall farmer readiness to implement new technology. They found that the three primary reasons farmers delayed adopting new technology were uncertainty about future markets, fear of crop failure, and threat to their own food security. Keeping these factors in mind, it is important to consider past successes and failures in the development of site-specific farming machinery. Any new farming implements should limit the financial risks farmers feel when considering such investments.

Methods—Approaches to Collaboration for Agricultural Improvement

Table 1 summarizes our research objectives and describes the research tools and methods we used to achieve each.

Table 1. Methodology Work Table

Objectives:	**Research Tools:**
1. Documented current practices and technologies used on local farms	Identification: Stakeholders, setting Mapping: Location of farms Observation: Tools, planting, irrigation, land, residents Documentation: Photography, recording Interviews: Semi-structured farmer interviews Interviews: Semi-structured government interviews
2. Evaluated farmer perceptions of new agricultural innovations, with regard to their existing challenges	Observations: Tools, planting, irrigation, methods Documentation: Photography, recording Interviews: Semi-structured farmer interviews Interviews: Semi-structured government interviews
3. Developed a rubric to guide the design process of appropriate agricultural technologies	Synthesized local farmers' needs and criteria with appropriate technology tenants Farmer interviews; scholarly research
4. Developed an appropriate innovation to address the farmers' greatest challenge	Applied design rubric and generated sample product and process

Our first objective was to document the current practices and technologies used on local farms. In order to assess whether village proximity to a substantial urban center would affect their practices, we chose to focus on sites within a 20-kilometer radius of Mandi Town in Himachal Pradesh. This radius allowed us to evaluate the direct impact of Mandi Town.

To ensure that we sampled an approximately equal distribution of farms, we divided the area surrounding Mandi Town into four geographic sectors. Quadrant I is found northeast of Mandi Town, Quadrant II is northwest, Quadrant III is southwest, and Quadrant IV is southeast. We visited four to five sites per sector, choosing at least one village near Mandi Town and at least one approximately 20 km from Mandi Town. For the remaining sites in each sector we selected villages that would offer the best distribution or provide data for a large portion of land not yet accounted for in a survey. We recorded each location on a map. The team conducted 36 farmer interviews in 18 local villages to identify irrigation, sowing, and harvesting techniques. When approaching farmers in each village we used a sample of convenience. As we gathered data from these four sectors, we categorized similarities in farming methods in an attempt to generalize typical farming practices across the region.

The surveys were typically conducted in Hindi, with team members asking prepared questions and recording the answers on a note sheet in English or Hindi. Our interviews were semi-structured, so as not to risk missing important concepts that could be explained through dialogue (Newton, 2010). At the conclusion of the interview, the team filled out a document recording farmer responses, the nuances of the conversation, and any other important information. These answers were later uploaded into an Excel datasheet to identify trends and create the appropriate visuals for representing our data. We also used direct observation and photography to record information on topography, field/terrace size and shape, and general layout of the farm. Photography was also vital in documenting available tools, with the team capturing an image of various farming implements as permitted by the landowner.

Our second objective evaluated farmer perceptions of new agricultural innovations, with regard to their existing challenges. The framework to capture this data was already established by our first objective, and the responses for these questions were captured simultaneously with objective one. These questions differed however because they focused on understanding the perceptions attached to changing or adopting a new technology. This also provided respondents with an opportunity to present their own perspectives on the challenges they faced, and catalyzed them to ask for solutions. To expand on this objective, we asked farmers if or how they would like to improve their current tools or processes. These answers were recorded in a similar fashion to objective one, eventually being uploaded into an Excel data sheet. We again used photography as a method of documenting the nuances of farming challenges.

To accomplish objective three, we created a rubric to guide the design process for appropriate agricultural technologies. This rubric was a natural extension of the six sides of appropriate technology previously researched and presented in the background section. We synthesized this with regional data and the reported challenges faced by farmers. Our criteria were reached through the careful understanding of the interview responses. By using our regional data, we ensured that our rubric could address the specific social and technical aspects of users in this area.

Our fourth objective was to develop an appropriate innovation to address the respondents' greatest challenge. Testing our new design procedure, we developed a process and product that satisfied our requirements for appropriate technology and that solicited user feedback in the design phase itself.

RESULTS AND DISCUSSION

We gathered data to identify appropriate innovations that might improve local farming practices. Results and discussion appear below.

Objective 1. Practices and Technologies

The current age of our participants ranged from 22 to 70 years, the average age being 42. These individuals worked almost exclusively on terraced farms with their families. Household size ranged from 3 to 17, with the average number being 6 co-habitants. In terms of division of labor, men tend to take responsibility for ploughing and tilling (manual or mechanized), sowing, pesticide spraying, and fertilizer spreading. Children often participate in weed removal, fertilizer spreading, and harvesting. Women are most often responsible for weed removal and harvesting. The education level of respondents (the majority of whom were head of household) ranged from no formal education to graduate studies. In total, 22 out of 36 had passed the 10th grade, and all had been farming since childhood. Most of the farmers had secondary sources of income, ranging from shopkeeping to government jobs. Proximity and secondary employment increased the frequency of their visits to Mandi Town.

The size of the targeted farms ranged from 1 bigha to 40 bigha, a local unit of measurement ranging from ⅓ to 1 acre. In Himachal Pradesh, 12.5 bighas are equal to one hectare. All farms grew corn and wheat, corn exclusively for sale, and wheat typically for personal consumption. Farmers also grew a variety of household vegetables at their own discretion, either for sale or consumption. The frequency of cultivation of each crop is visible in Figure 4.

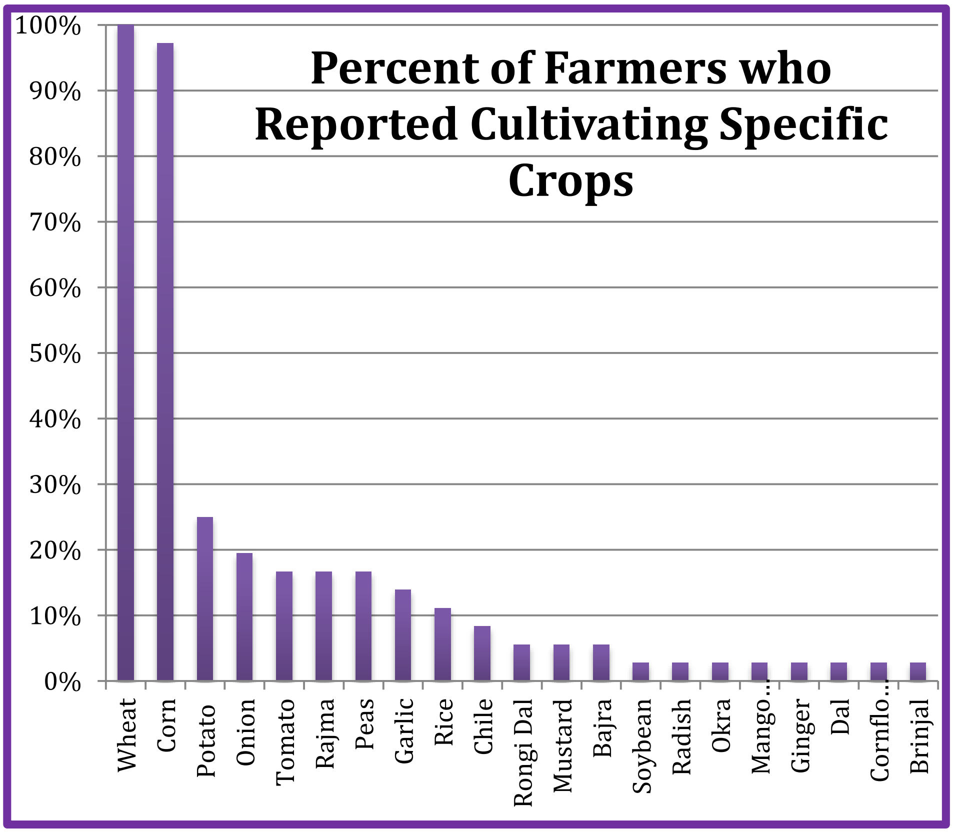

Figure 4. Farmers reported their choice in crops, arranged here by popularity.

Corn and wheat are the most prolific crops. Their specific procedures are summarized below in Table 2.

Table 2. Summary of corn and wheat cropping habits.

	Corn		**Wheat**	
Sowing/Harvest Times	Late July	Early December	Late December	Early May
Planting Method	Seeds planted one by one in a trough approx. 3-4 inches apart		Seeds scattered by hand over ploughed field at distances from 0.5-2 inches apart.	
Harvesting Method	Stalks cut down by thick darati		Stalks cut down by thin darati	
Threshing Method	Ears are sundried over several days, husk removed by hand.		Crop threshed by petroleum-fueled mechanical thresher or oxen-powered disrupter. Choice of methods dictated by expense and availability.	

Before the planting phase, fields are tilled for rocks and residual root systems. The proportion of respondents that used the oxen-plough method was 30/36, a majority that transcended elevation differences. We found 13/36 interviewees have used a motorized tractor on their lands as a rental or a personal purchase. The farms at higher elevations were less likely to have used a tractor on their field, see Figure 5. Crops were grown over spring, summer, fall, winter, and kharif (a season which extends from April to September). Grains were cultivated from seed, yet vegetables were grown from seedlings. All seeds and seedlings were purchased at markets. Sowing and harvest deadlines are traditional for each crop, but there must be a rainfall before sowing. Farms with irrigation facilities, however, do not need to strictly abide this rule. Furthermore, farmers can delay planting up to 10 to 12 days in adverse (dry) conditions.

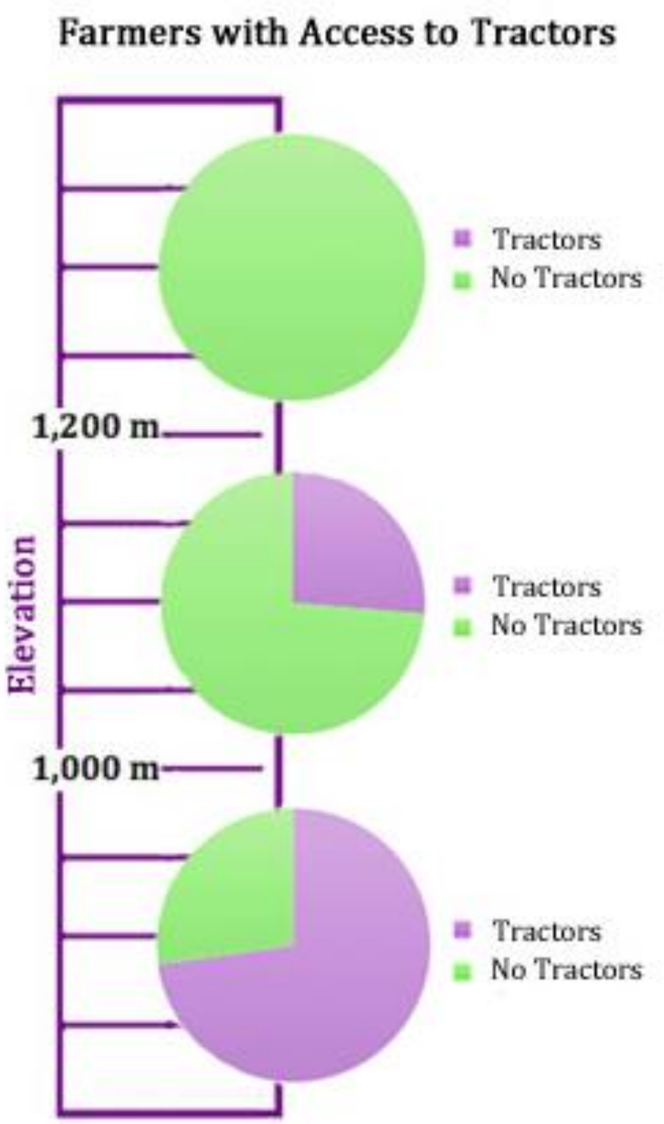

Figure 5. The relationship between farmer access to tractors and elevation.

Farms with irrigation systems were able to provide surplus vegetables to Mandi markets. Irrigation technology was not widely implemented, though, with 19/36 of respondents reporting reliance solely on rainwater. Current irrigation systems rely on pumps to pull water from the river to deposit on the fields, or collected rainwater from roofs and patios. Available subsidies cover Rs. 15,000 of irrigation implementation and the 600m of pipe. Additional coverage is provided for power tillers and greenhouses. Purchase of tractors and threshers are not subsidized.

The most commonly used local tools included the plough, ax, darati, fawara and faruda. A detailed presentation of these tools can be seen in the Tool Catalogue in the Project Outcomes section. A typical plough is adapted from a single blade mounted to a frame at approximately 45 degrees. This frame is dragged behind two oxen across a field to either disrupt or make grooves in the soil (Figure 6). The ax follows classical design, and the darati resembles a scythe. This tool is available in two different girths--thinner blades are used to harvest wheat and cut grasses for livestock, while the thicker blades are used to harvest corn and remove thicker brambles. The fawara and faruda displace and dig soil.

Objective 2. Farmer Perceptions on Agricultural Technology and Challenges

In response to our interview questions measuring receptivity to innovation, the farmers expressed interest in implementing technological solutions and making better/modern devices more available. Most were cognizant of new technologies such as seed planters, tractors, and power tillers, and frequently reported having had experience operating them. There was no direct correlation between distance from Mandi town and degree of technological receptivity, although Mandi Town was the primary location for the purchase of traditional and modern farming tools. Only respondents from Rewalsar, Pandoh, and near Ner Chowk purchased their tools at these respective towns. Respondents were interested in owning equipment that might ease the burden of certain tasks reported below.

Cost/benefit was the greatest concern for any potential device introduced to their farms. We observed instances in which agricultural machines were available as rentals.

Figure 6. An example of traditional farming technology in Bindravani, Mandi District.

We also observed communal threshers during our walks to farms. We only encountered 13/36 respondents who had purchased a small tilling machine, pesticide sprayer, or small tractor. Half of these individuals were stationed below 1,000 m. The cost to own these devices is considerably greater than the simpler, petroleum-independent, manual options available. A breakdown of comparable costs are in Figure 7.

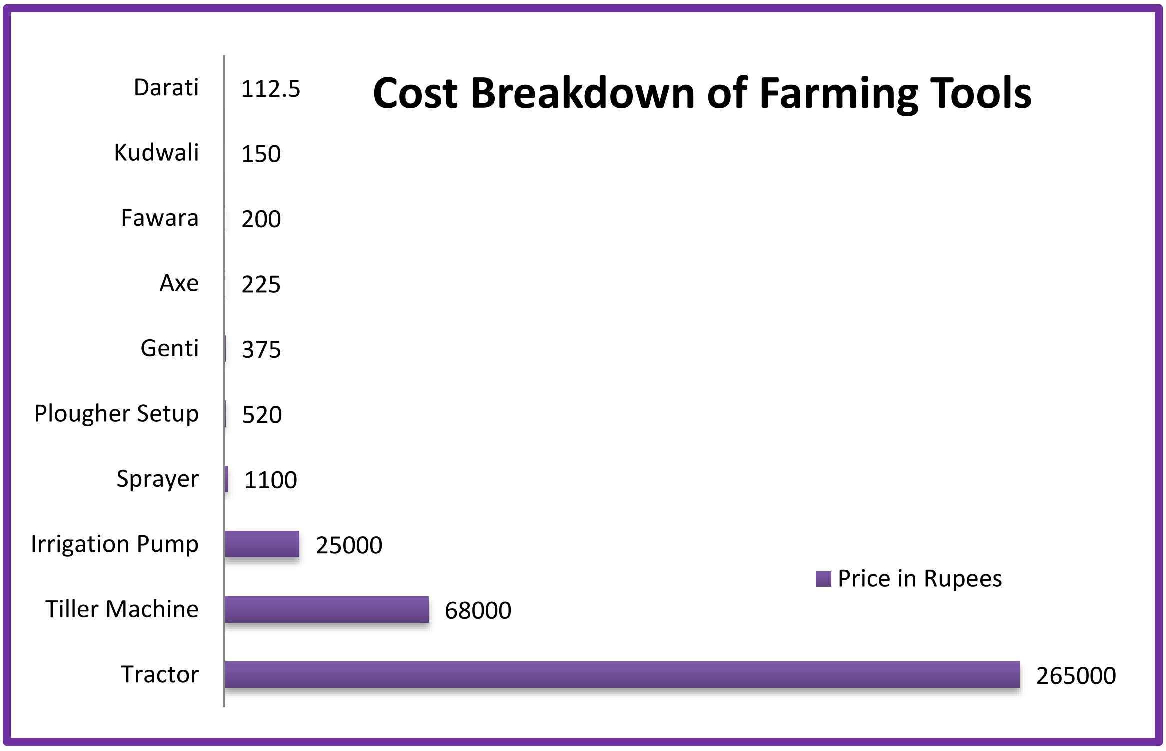

Figure 7. Farmers pay approximately 100-500 rupees for traditional tool while the mechanized counterparts sell in the order of thousands.

In addition to cost, respondents were also concerned about the ability of new technologies to remain functional on a terraced landscape. We observed that the paths between farms in the villages are steep, up to 50 degrees, and the height between terraces ranged from 1 to 4 meters. Secondly, the terraces themselves can be narrow, we observed several being less than a meter wide. Size and maneuverability in this uneven landscape appeared paramount.

A third most frequently reported concern about device functionality was the complexity of operation. Farmers expressed interest in owning "semi-tech" devices, or non-electronical, automated machines. Each village we visited had at least one blacksmith or mechanical workshop that could facilitate repair of simple equipment. Farming tools were taken to these garages for repair and modification using rudimentary equipment such as a drill press, hammer, or anvil.

Existing Farming Challenges

The most severe impediments to a successful harvest were reported as unpredictable weather patterns (particularly rainfall frequency), animal attacks on crops (monkeys and wild pigs), and decreasing field fertility, in this order of gravity. Furthermore, according to government statistics, only 20% of the cultivated land in Mandi is irrigated by sponsored systems or from diverted streams and groundwater. We observed only two instances of sponsored irrigation systems and no farmer mentioned using the diversion or well-based watering techniques, given the scarcity of mountain streams.

The majority of respondents would grow more vegetables for personal use, and eventually sell, if they had access to a system for irrigation. Inconsistent rainfall makes it difficult to successfully grow water-intensive vegetables such as onions, black-eyed-peas, ginger, garlic, and rice. On the other hand, farms with government-sponsored irrigation are able to increase yields so as to supply vegetables to the Mandi markets. These systems operate by pumping water from local rivers. Therefore, there is a distinct preference towards river-bordering farms for the implementation of irrigation technology. The Department of Agriculture is planning to implement micro-irrigation sprinkler systems soon, but to unspecified candidates. Irrigation of crops is entirely farmer driven at this point, limited by access to water sources and funds to build watering systems that incorporate pumps, channel diversions, or collection systems.

Farm upkeep could be made more efficient. Certain processes were reported to be especially labor intensive: corn planting, shucking, and non-mechanical wheat threshing. Mechanical threshing is an option, but is reported to be uncomfortably expensive for rent and operation. The by-hand alternatives demand large amounts of time. Farmers expressed interest in automating these procedures, but the most pressing of these requests were, in order of ascending frequency, a device for field tilling, irrigation, and seed planting.

A final, and concerning common problem was decreasing field fertility and expensive seed price. Every year, their fields are producing less while seeds and vegetable seedlings are reported to be expensive. Farmers were keen to see government assistance in rectifying these trends. Mandi District manages farmer education by holding training camps. They are held at a larger local village once a month, in each of Mandi District's ten blocks. Farmers can report what aid they need in order to be successful, and soil testing is provided for free. The government identifies seed availability, seed planting, animal attacks, and water availability to be the greatest problems faced by farmers. These findings mirrored our interview responses, but we were surprised to hear monkey attacks are becoming worse. Animal attacks on farms are managed by Department of Forestry—this problem falls under their jurisdiction. Farmers we interviewed were not aware of these camps or how to apply for subsidies. At the same time, low attendance has baffled the Department of Agriculture. As it stands, there are subsidies up to 40% of the cost for agricultural devices for the average farmer and 50% of the costs for farmers who are women and members of scheduled castes (SC), scheduled tribes (ST), and the impoverished. The subsidies will cover any agricultural device which has been investigated by the KVK (Krishi Vigyan Kendra) and been granted approval by the University of Agriculture.

Objective 3. Appropriate Considerations to Local Farming

We designed a rubric regionally-tailored to primary farmer needs, affordability of possible tools, environmental demands, acceptable device complexity, cultural practices, and basic criteria for usability. Our interview with a representative from the Department of Agriculture shed light on some conflicts of perception. Farmers reported their most profitable crops to be vegetables and corn. The Department of Agriculture specified peas and tomatoes to be the most profitable vegetables, but claimed wheat to be a for-profit crop. While the department agreed that corn and vegetables were the most problematic and time consuming to grow, he informed us that 25% of the population used mechanical threshers for wheat and no one uses oxen for agricultural labor, in spite of our findings to the contrary.

While farmers are eager for government aid, they are ignorant of existing subsidy programs that facilitate the purchase of modern implements. The typical handheld tool costs from Rs. 100-400 rupees, while the slightly more advanced options, such as pesticide sprayers, cost in the order of thousands of rupees. A subsidized, semi-tech device could be found at a price ranging Rs.1,000 to 10,000. Subsidy benefits for women and lower castes have even greater benefits, but are often not realized, as they must be claimed in person upon the purchase of a device. Women are typically at home to maintain the house, while the impoverished perceive the cost of transportation and purchase of the devices as unaffordable. These challenges need to be addressed, but the government hopes that someday subsidies can be provided for all modern devices and farmers will be actively involved in ongoing education.

Any device designed for this area would need to operate on terraced farms. Their shape is typically long, narrow, and gently curved, and therefore need be compact to be able to perform tight maneuvers. The device must be lightweight, durable, and ergonomic to carry up the terraces from field to field, at inclines ranging from mild to dramatic. To preserve weight, it should not rely on expensive fuel.

Increasing the precision of existing practices will translate into greater time efficiency. We observed that it was difficult for a single operator to simultaneously control the speed of the oxen and the angle of the plough. It is clear that greater control over these chaotic practices can pave the avenue for higher efficiency. Non-automated wheat threshing, oxen tilling methods, harvest of randomly planted crop, and the entire production of corn were cited as the most time expensive. Devices that accelerate these processes could dually serve to make the processes easier and less expensive. Given the for-profit nature of the corn harvests, the economic factor of this advancement can have far reaching effects.

The visual summary of engineering criteria matched to local socio-economic features can be found in the Project Outcomes section. Future teams should assess their problem statements according to the six sides of appropriate technology before beginning their design project. Our rubric can serve as a guide to the primary design points so a student's innovation or a farmer's improvisation can be integrated into the existing societal infrastructure and agricultural industry.

Objective 4. Design an Appropriate Innovation

Our results indicated an automated corn seed-planter would be a highly beneficial product for local farmers. To meet farmer demands, we designed a corresponding device that would appropriately address this issue.

Consulting the rubric previously created in Objective 3, our team developed a corn seed planter that would remain functional on the challenging terraced terrain. Design parameters for this device include the ability to perform tight turns with minimal disruption to the soil, and maximum ease of use for the operator. Further criteria developed through the examination of the rubric were that the design was durable, safe, and lightweight. The minimalist design ensures lower overhead production cost, in hopes that this technology will be marketable to all local farmers in the future. After the ideal design was completed, we gathered materials and assembled an initial prototype by means and manners analogous to ones found in Mandi market. Additional detailed computer aided design (CAD) renderings and photographs appear in the outcomes section.

Our data also indicated that irrigation systems, especially for villages at high elevations, are in significant demand. We developed the plans for an irrigation system that can address the needs of an average hilltop farm. This system could be further refined if tested at a village-technology center, or a campus farm. Important data on approximately how much water can be collected from each rainfall, the exact quantity to properly irrigate an average field, and so forth could be extracted from an appropriate trial field. On-site trials are necessary to determine the total efficacy of our designs.

Discussion

The data revealed 3 key challenges faced by the farmers:

1. Laborious nature of corn planting and harvesting
2. The lack of irrigation facilities
3. The consequences of damage from animals

The typical farmer lacked irrigation on steep terraced farms and was most concerned about automating or facilitating manual tasks, and protecting fragile crops. However, our interviews gave us insight to more nuanced elements to the farming lifestyle. We expected the most pressing need to be related to the planting process. Our preliminary research indicated Himachal Pradesh was prosperous and independent from subsistence agriculture. Indeed, many requested assistance to ease the sowing process. However, we were surprised at the profound concern expressed over irrigation, despite the state's "water surplus". Farms with irrigation were more productive and far wealthier. In turn, this meant that they had the means to access more advanced technology and to experiment with more profitable crops. These opportunities were denied to the farmers on more isolated or elevated locations.

One farm in Lagdhar reported hundreds of monkeys raiding his fields along with the local wild pig and bear populations. We had considered that animal raids might be a frequent nuisance, but he proved to us the devastating severity it posed when left unchecked. A failed crop is a net loss of food for the family as a whole, and this is especially concerning when compounded with field infertility. Minimizing crop failure is a priority, but making the farming process less taxing could enable the farmer to spend more time investing in secondary employment or crop security measures, which could provide a more dependable safety net in times of crisis.

Farmers are unaware of government schemes aimed to help them. We observed that while camps are held in relatively local venues, advertising and outreach are not reaching their targets. The camps can potentially be useful as venues for transfer of training and petitions. Attendance might be increased through more relevant advertising and deliberate outreach mechanisms. Additionally, Mandi Town should be a hub of agriculturally innovative and affordable devices. It is the primary location for tool purchases, both subsidized and retail.

We found 7/36 respondents explicitly cited collaborating with neighbors if they needed additional help during planting or harvesting. This cooperative disposition is extended to the shared ownership and renting of modern agricultural devices, a practice more pronounced in villages near Mandi Town. If intelligently engineered devices are beyond the users' economic allowance, perhaps marketing new devices to communities could be an option. Most of our respondents also requested low/semi tech devices. These must be intuitive for the user and the mechanic of the village garages. Complex electrical repairs may be beyond the expertise and resources of farmers in Mandi District.

Our findings allowed us to reflect on the designs and prototypes made by previous IIT teams. In retrospect, they proved to be highly complex and reliant on electronic components. These design proposals included a battery powered seed planter, an electronic drip-irrigation system, and a quad-copter pesticide delivery system. Innovation should be collaborative in order to produce intuitive and functional devices for local farmers.

PROJECT OUTCOMES AND CONCLUSION

Our research resulted in two key project outcomes:

1. A set of curricular recommendations that can enable students to work with an appropriate technology rubric for innovation in small villages, and
2. A case study of two agricultural prototypes that we used to test our own program.

We begin with our recommendation for technology design students.

1. Curricular Recommendations

To enable students to work with users in small villages, we developed a set of curricular strategies. First is the use of our Appropriate Technology Rubric for design and innovation courses. Second is a resource guide that contains an archive of existing tools used in the region. Our third and final item suggests the foundation of an experimental farm on campus. To facilitate collaboration with local farmers during the design process, our team offers the following strategies: Innovation students should utilize the appropriate technology rubric from pre-project conceptualization through completion, in order to ensure maximum compatibility of any technology within the region's existing infrastructure as a whole. An on-campus farm plot should be developed where sample technologies can be tested in a realistic environment without interfering with day-to-day activities in working communities. The campus plot might be managed by ISTP/Design Practicum students and faculty, and equipped with a variety of local tools and IIT-developed implements. Villagers can visit this plot to directly observe the benefits and/or provide input on technologies currently being developed.

By using an appropriate technology rubric at the start of a project and by collaborating early with users, design students can optimize their time. Complexity and usability will be addressed early in a prototype's life. After completing a prototype, it would be beneficial to check it against the rubric and through user testing.

The farm plot should replicate terraced farming, simulating the dimensions and soil conditions. Student designers will be able to directly engage the targeted environment, and will be able to maintain long-term demonstrations of their innovations. Local farmers could be invited to see the viability of newly developed ideas and provide feedback on field performance. This test farm could provide a controlled environment for future students testing any outdoor or agriculture related technology. In the future, IQP and ISTP projects will have the opportunity to focus on energy availability, technological education or government involvement, and providing appropriate technologies that can be immediately placed into use on regional farmland. Innovators can approve their technologies for government subsidy by submitting designs for evaluation by the KVK and University of Agriculture. This follow-through will only enhance successful implementation.

The following is the Appropriate Technology Rubric, customized to the needs of farmers surrounding Mandi Town (Figure 8).

Existing Needs

- Protection of fields against raids by animals
- Land fertility
- Seed affordability and availability
- Planting Techniques
- Irrigation Techniques
- Harvesting Techniques
- Threshing Techniques

Affordability Limits

- Approved for government subsidy
- Rs. 100-250 for small handheld options
- Rs. 1000-10,000 for "semi-tech" options
- Maximum Rs. 20,000 for communal options
- Minimal to no operating costs
- Repaired by manual or standard procedures
- Implementation leads to increased farmer profits

Environmental Conerns

- Is constructed from inert materials
- Is biocompatible with local flora or fauna
- Requires no fuel or fuel from a sustainable source
- Demands locally sourced materials for parts
- Endures rocky soil and variable levels of moisture
- Preserves soil integrity
- Operates with minimal waste of fuel, materials, or external resources

Technical Literacy

- Device has an intuitive assembly
- Parts are easily replaced
- Moving parts are isolated from working environment
- Design is operated by following minimal number of steps
- Design does not require proficient electronics knowledge to operate
- Design documentation is provided to user
- Design is safe under all conditions

Cultural Sensitivity

- Product/procedure is integrated into current techniques and practices
- User feels comfortable with the device or process
- Design considers for specific operators
- Design takes into account loose traditional clothing
- Documentation is provided in a native language
- Technology is legal according to Indian and International Law
- Design is accesible to all social groups

Terrace Usability

- Operates on inclines up to 45 degrees
- Operates on 1/2 to 5 meter wide terraces
- Design paramaters directly controlled (manual, no automation)
- Designed for minimal points of failure
- Less frequent maintanence required than present methods
- Transportable by one or two workers
- Manueverable by one worker

Figure 8. The appropriate technology rubric for farms surrounding Mandi Town

This rubric is accompanied by documentation of the traditional tools that are commonly used in the area (Figure 9). A full version of this summary can be found in the supplemental materials.

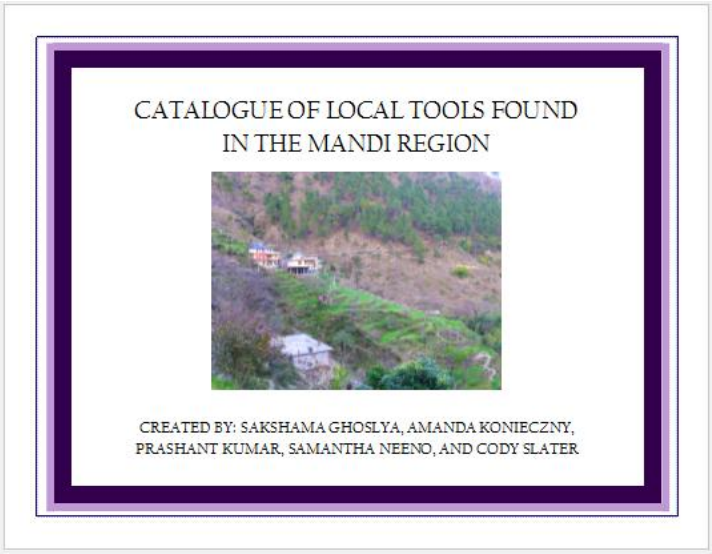

Figure 9. The cover page of the tool catalog.

2. Prototype Tests for Corn Seed Planter and Roof-top Irrigation System

These designs represent the first devices produced while following the guidelines of the appropriate technology rubric. As an example for how this rubric can be applied, the corn seed-planter has been graded for regional applicability. We recommend that follow-up researchers take our prototypes to local farms and record their input, making necessary adjustments to the designs.

The CAD design for our corn seed planter (see Figure 10) scored 27/33 (see Table 3 below) for applicability. However, the prototype can still be refined. Primarily, future designers will have to optimize the mechanism for depositing individual seeds. At present, a bicycle chain drives an auger, and has proven difficult and costly to build. A future student team should look into developing a cheaper, simpler option. This team should also dedicate close attention to the ergonomics and overall functionality of the device. Our team was limited in design time and may have overlooked options that could increase functionality. With these project outcomes, future projects may address relevant regional challenges from a social as well as technological perspective.

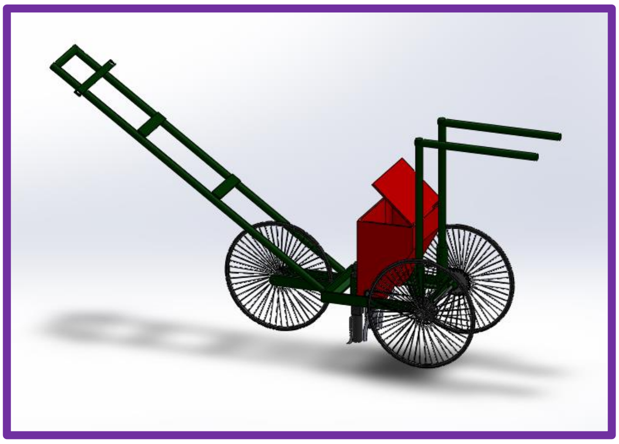

Figure 10. CAD rendering of a mechanical seed planter for corn.

Table 3. Appropriate technology rubric applied to our corn seed planter.

Device Name:	Seed Planter
Existing Need Met:	Planting Techniques

Affordability Limits		Environmental Concerns		Technical Literacy		Cultural Sensitivity		Terrace Usability	
Subsidy Approved	-	Inert Materials	+	Intuitve Assembly	+	Resembles Current Practices	+	Incline	+
Appropriate Price	+	Bio-Compatible	+	Replaceable Parts	+	User Comfort	+	Variable Width	-
Inexpensive Operation	+	Fueled Responsibily	+	Isolated Mechanisms	-	Operator Consideration	+	Direct Control	+
Manual Repair	+	Locally Sourced	+	Easy to Use	+	Clothing Consideration	-	Minimal Points of Failure	+
Increases Profit	+	Withstands Elements	+	Electronics Independent	+	Native Language	-	Infrequent Maintanence	+
		Preserves Soil	+	User Manual	-	Legal	+	Tranportable	+
		Minimizes Waste	+	Safe Design	+	Accessible	+	Manueverable	+
Individual Grade	4 of 5		7 of 7		5 of 7		5 of 7		6 of 7

Overall Grade **27 of 33**

Conclusion

In collaboration with village farmers in the Mandi District, we were able to profile local farming practices, needs, and the use and perceptions about local agricultural technologies. This profile can enable future tech designers at the IIT to produce appropriate technological solutions that ease the burden of everyday farm work and increase productivity. In the future, student teams can use our rubric and catalogue to learn about local needs and practices. They can also work in conjunction with government schemes for agriculture to enhance the linkages from policies to local farms. These schemes have the potential to provide monetary support and training for tech advancement, but as we have shown, they often do not reach those who need it. Finally, developing an on-campus village technological innovation center could improve the collaboration that the IIT has with its agricultural neighbors and allow future IIT students to move from prototype to user testing. This plot could be a demonstration site that highlights accomplishments and models as well as the positive impact of community university collaboration. We hope our project outcomes form a precedent for future social impact.

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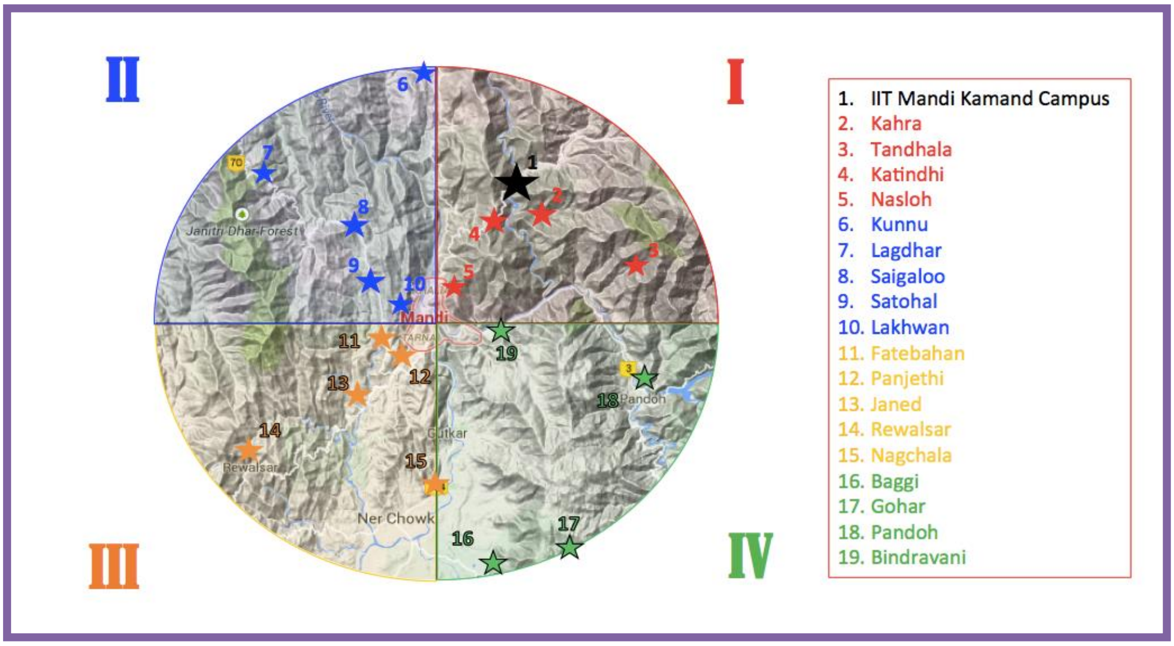
SUPPLEMENTAL MATERIALS

FOR METHODS SECTION

Sector Map



Farmer Questionnaire

Hello Madam/Sir, we are from IIT Mandi and are engaging in a survey of local farms. We are interested in learning about your agricultural practices and what you grow. May we have some of your time to interview you about your experience farming in this region?

We first would like to learn more about who you are, the following questions are for our records and your identity will remain anonymous.

About the Farmer and their Family:

1. Age of person being interviewed?
2. Level of education of person being interviewed?
3. Population of village?
4. Number of family members in household?
5. Aside from farming, do you do any other kind of work?
6. How often do you travel into a large town? Mandi or otherwise? For what purposes?

We will now ask you about the land you farm:

About the Land:

1. How long have you or your family been farming?
2. What is the size of your farm?
3. Who works with you on the farm?
    a. What tasks do the men help with?
    b. What tasks do children help with?
    c. What tasks do women help with?
4. How do you access water for your farm?
    a. Groundwater River Only Rainfall Tank Water Supply
5. If you could change how you water your crops, would you choose to grow different crops?

In this section, we will now ask you about the crops you sell and the overall management of your farm:

About the Crops:

1. What crops do you grow during the Fall?
2. What crops do you grow during the Spring?
3. What crops do you grow during the Winter?
    (Answers for Fall/Spring/Winter)
    a. What crop do you grow the most of?
    b. Do you sell the produce or keep it for your family?
    c. If you sell your harvest, what crop is most profitable?
    d. What crop costs you the most money to grow? Why?
    e. What are some problems you face that reduce the yield of a harvest?
4. Have you noticed a change in harvest yield over the last 5 years? Why?
5. Have you changed how you plant or harvest crops over the last 5 years?

In this section, we would like to ask you about your farming practices.

About Farming:

1. Do you till your land before you plant?
2. When do you decide to plant your crops? Is it right after it rains or when it is dry?

3. Could you please explain how you plant and harvest each crop (For crops with most area, max 3)?
4. Which crops take the most time to plant? How long? Why?
5. Which crop is the most difficult to plant? Why?
6. Which crops take the most time to harvest? How long? Why?
7. Which crop is the most difficult to harvest? Why?

Now we would like to ask you about technology.

About Technology:

1. Do you have access to electricity?
2. Do you need electricity for any of your farm practices?
3. Do you have a cell phone or computer? How do you use them?
4. Have you ever used any electric or petrol powered farming tool?
5. Are you more interested in high tech or low tech farming devices?
6. Have you tried to change the way you sow, irrigate, or harvest? Could you describe your experience?
7. What concerns do you have about buying new equipment to use on your farm?
8. If an affordable device was available, what factors would make you hesitant to purchase it?
    a. Not sure about the market
    b. Fear of crop failure
    c. Threat to food security
    d. Lifespan or quality of device
    e. Others (please specify)

Now we would like to discuss the kinds of tools you are using.

About the Tools:

1. What was the last piece of equipment you purchased for your farm and when?
2. Where did you get it?
3. How much did you pay for it?
    a. What should have been changed to make it better?
4. What was the last piece of equipment you made?
    a. What should have been changed to make it better?
5. Do you have any specific concerns about your current farming methods?
6. What sort of device would you like to see in the future?

If you have the time, would you mind demonstrating some of the tools you use?

Demonstrations:

Ask: How is each tool used?

Government-Representative Questionnaire

Hello Madam/Sir, we are from IIT Mandi and are engaging in a survey of local farms. We are interested in learning about how agricultural practices and agricultural innovations are supported and distributed. May we have some of your time to interview you about your experience working with this region?

We first would like to learn more about the demographics of your constituents. The following questions are for our perspective and to provide specific context of our data.

About the Farmers and Region:

1. Over what region/area/district do you manage?
2. How do you contact farmers in your region?
3. How frequently do you communicate with farmers about their farms or crops?
4. Do you perceive a difference in the needs of low and high elevation villages?
    a. What sort of needs do villages at lower elevations possess?
    b. What sort of needs do villages at higher elevations possess?
5. Do you own or operate your own farm?
6. Aside from farming, what are the most popular secondary forms of work?

In this section, we will now ask you about the crops around Mandi:

About the Crops:

1. What types of crops are grown in the region?
    a. Which crops are most abundant?
    b. Which crops are most profitable?
    c. What crops are the most problematic to grow in the region? Why?
2. What are some problems you are aware of that reduce the yield of a harvest?
3. Have you noticed a regional change in harvest productivity over the last 5 years? If yes, what has caused this change? If no, what factors have caused yield to remain stable?

We will now ask you about the farmland around Mandi:

About the Land:

1. What is the size of the average farm that you work with (large, medium, or small farms)?
2. In this region, what is the conversion from bigha to hectares?
3. What do you think are the greatest challenges that farmers face?
4. Are there any local policies to address these challenges?
5. How long have these policies been in place?
6. What factors are considered when deciding which farms will receive aide? (land size, productivity, elevation?...)

Now we would like to ask you about technology on farms:

About Technology:

1. Do farmers typically have access to electricity?
2. What sort of modern agricultural machinery is available to farmers in this region?
3. How common is the use of modern agricultural machinery in this region?
4. Are farmers hesitant about buying agricultural devices?
5. Is there support for farmers who are interested in adopting an electric or petrol powered farming tool?
6. What methods exist to help farmers irrigate their crops?
7. Are there any irrigation systems that can be implemented in high elevation farms, far from a river or natural water source?
8. How does the subsidy process work?

Now we would like to discuss the kinds of tools farmers use:

About the Tools:

1. How do farmers plow their land?
2. How do farmers thresh their grain?
3. Are there any plans in place to educate farmers about new technology or practices?
    a. If yes, give details (cost, location, content, etc.)
4. What concerns have you heard from farmers about obtaining new farm machinery?
5. What concerns have you heard from farmers about future farming plans in the region?
6. What concerns have you heard from farmers about implementing irrigation on their farms?
7. What innovations do you feel could best serve area farmers?

FOR RESULTS SECTION

Summary of Local Crops and Cultivation Habits

Our team has finished the field work, visiting 18 villages around the Mandi Town as per our pre-decided sector divisions. As a result of all these field visits, we have developed a list of the crops grown by the farmers around the Mandi region. Their seasons, planting, and harvesting methods are as following:

1. Corn (In summer and Fall)
    - Till the ground to make it softer by oxen or power tiller or tractor
    - Sow the seeds one by one at a certain distances (approx. 3-4 inches)
    - Cut the plants and remove the husks
    - Put husks in sunlight and after few days remove corns from husks manually

2. Wheat (In winter)
    - Till the ground to make it softer by oxen or power tiller or tractor
    - Spread the seeds randomly by hand
    - Cut the crops by 'Darati'
    - Use thresher or oxen to remove wheat from crops

3. Potato (in winter)
    - Till the ground to make it softer by oxen or power tiller or tractor
    - make bit deeper rows by using 'Fawara'
    - put seeds one by one at certain distances (approx. 1 feet)
    - the dig potatoes by using 'Fawara'

4. Rajma (Kharif Season)
    - Till the ground to make it softer by oxen or power tiller or tractor
    - Sow the seeds one by one at certain distances
    - pluck from plants

5. Bajra (Kharif season)
    - Till the ground to make it softer by oxen or power tiller or tractor
    - spears the seeds randomly by hand
    - cut the crop by 'Darati'
    - separate bajra form crop by using animal?thresher

6. Ginger (In summer and fall)
    - Dig the ground approx. (5-6 inches) and put the small ginger as seed
    - Dig the developed ginger by ‘Fawara' or ‘Kilani'

7. Tomato (late summer)
    - Buy tomato saplings form market
    - Dig the ground (approx. 5-6 inches) and put the small tomato plant
    - Pluck tomatoes by hand

8. Cucumber (in summer)
    - Buy seeds from market
    - dig 2-3 inches and put the seeds
    - pluck cucumber by hand

9. Garlic (in spring)
   - Till/plough the ground to make it softer by oxen or power tiller or tractor
   - Irrigate the ground with high amount of water (irrigate first)
   - Put garlic saplings bought from market at certain distances
   - dig by tools or pull the plants from ground

10. Mustard (early spring)
   - Till the ground by to make it softer by oxen or power tiller or tractor
   - Spread the seeds randomly by hand
   - Cut the crops by 'Darati'
   - put in the sunlight and 'Thrash' by sticks to separate the mustard from crop

11. Peas (In late winter and spring)
   - Dig the ground little bit (approx. 1-2 inches) and put the seeds
   - pluck the peas husk from the plant

12. Bhindi *(Okra) (in summer)
   - Dig the ground little bit (approx. 1-2 inches) and put the seeds or saplings bought from market
   - pluck the Bhindi (*okra) from the plant by hand

13. Onion (In winter)
   - Till/plough the ground to make it softer by oxen or power tiller or tractor
   - Irrigate the ground with high amount of water (irrigate first)
   - Put onion saplings bought from market at certain distances
   - dig by tools or pull the plants from ground

14. Rongi dal (*black eyed beans) (in kharif season)
   - Till/plough the ground to make it softer by oxen or power tiller or tractor
   - Sow the seeds one by one at certain distances
   - pluck the husks of wrong dal from plants
   - Thrash the husk to separate ‘Rongi dal’

15. Radish (In late winter and spring)
   - Till/plough the ground to make it softer by oxen or power tiller or tractor
   - Spread the seeds randomly by hand
   - pull the whole plant or dig by using tools

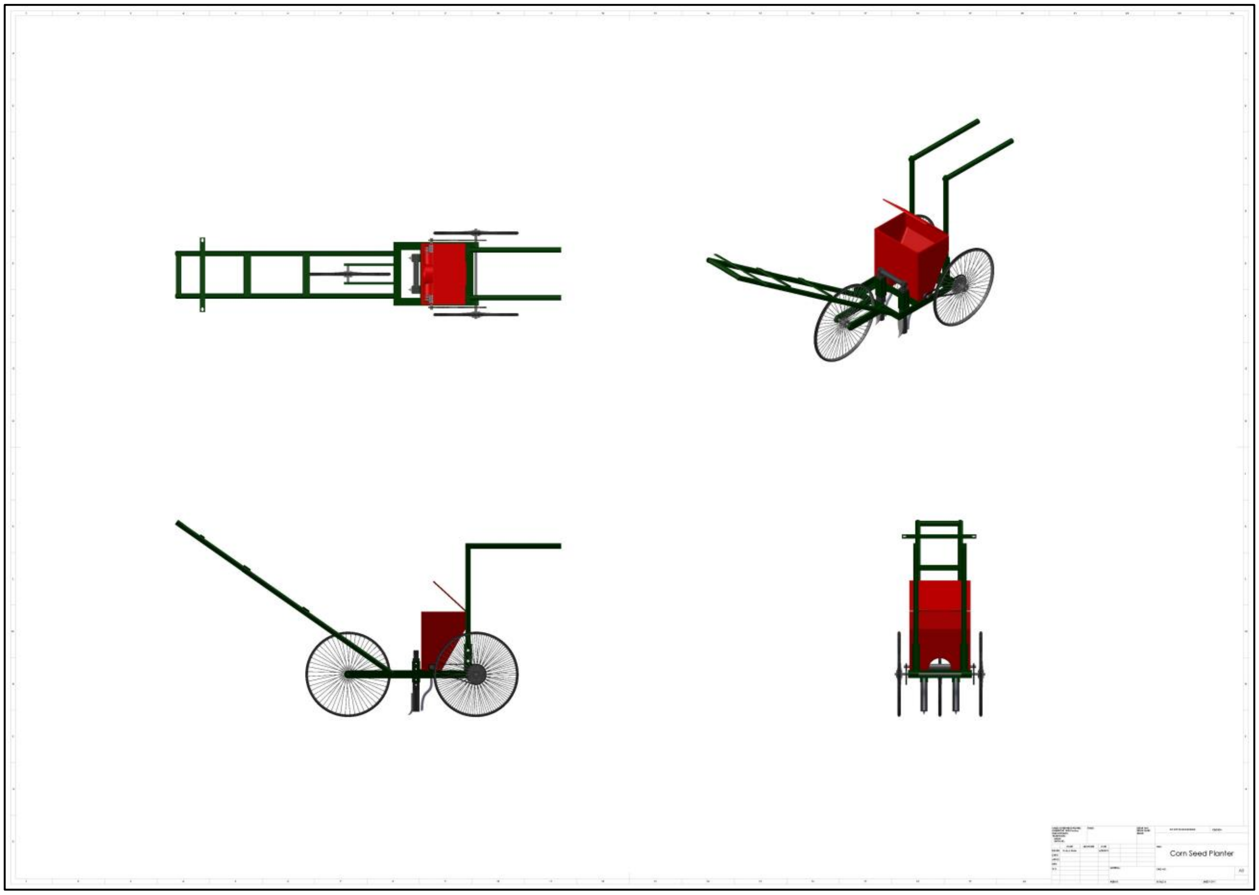
16. Brinjal (in summer)
   - Buy brinjal saplings form market
   - Dig the ground (approx. 3-4 inches) and plants the brinjal saplings
   - Pluck brinjal by hand from plants

17. Rice (in fall)
   - Till/plough the ground to make it softer by oxen or power tiller or tractor

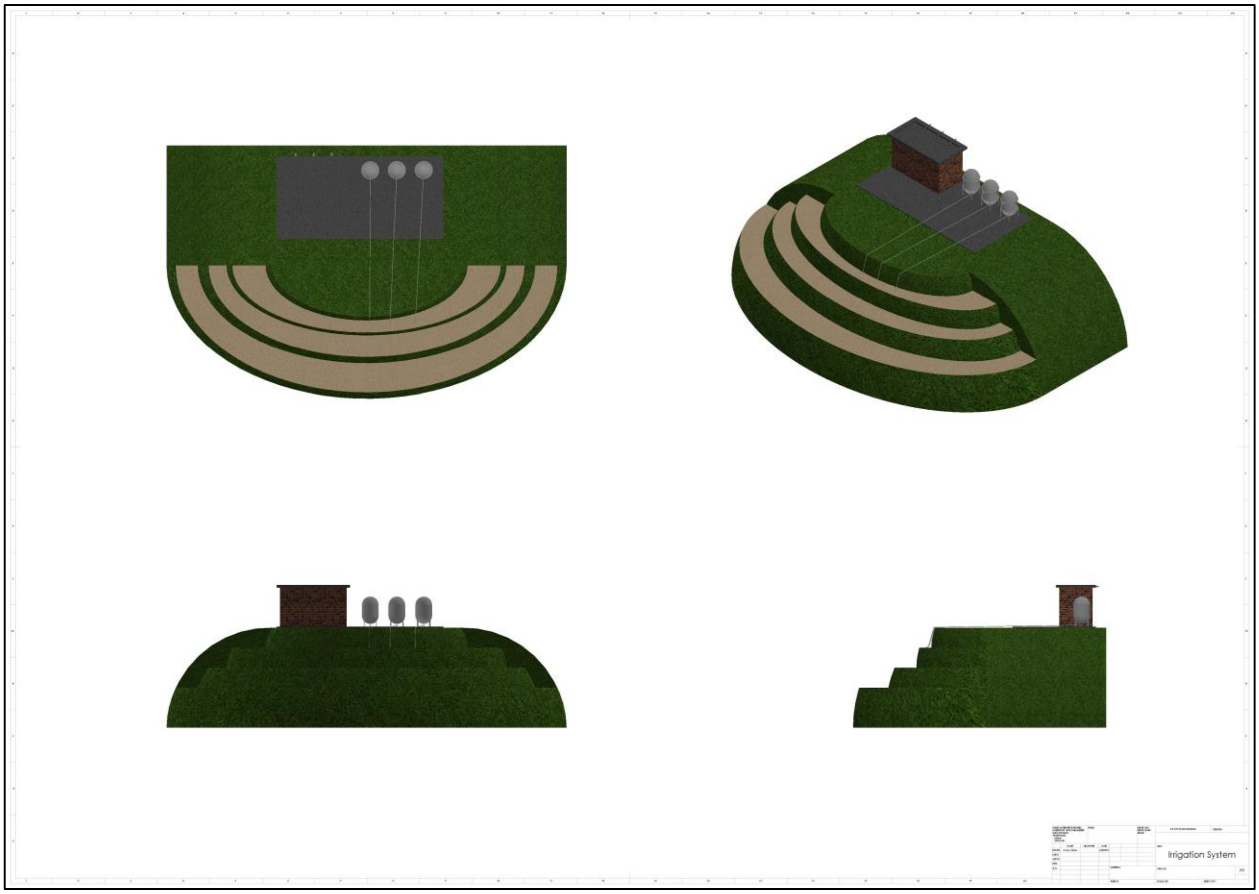
- Spears the seeds randomly and after around 1 month displace the saplings in some other muddy farms
- cut the crop by 'Darati'
- separate the rice from the crop by using animal/machine

FOR PROJECT OUTCOMES

Prototype Documentation: Mechanical Corn Seed Planter



Prototype Documentation: Rain-Water Collection Irrigation System



Tool Catalogue

CATALOGUE OF LOCAL TOOLS FOUND IN THE MANDI REGION

CREATED BY: SAKSHAMA GHOSLYA, AMANDA KONIECZNY, PRASHANT KUMAR, SAMANTHA NEENO, AND CODY SLATER

TABLE OF CONTENTS

Farming is an essential aspect of life for the people living in Mandi District. Most of these villagers have lived on their land for centuries and have been farming since birth. The implements that are used on these farms consist of a variety of traditional and modern devices. Concerning traditional tools. it can be difficult to find a complete record detailing their forms and functions. Our team has compiled this catalogue in order to provide this information to a wider audience. Additionally, we have included a rubric, developed from our own research, outlining an approach to designing, testing, and implementing agricultural technologies in this region.

TOOLS

4

GENTI

The genti is a tool used to hand-till the ground , making it softer for planting seeds . This implement is operated by a single person. The handle is generally made of wood and 0.5 meters long. The pick-like head is made of iron.

FAWADA

This tool, known as the fawada, is analogous to a contemporary shovel, serving to dig and spread soil, manure, etc. The handle ranges from 0.5 to 1 meter and is made of wood. Its iron head is constructed locally.

5

KULHARIDI

A Kulhari, synonymous with an axe, is primarily used for cutting wood. It's head is typically constructed of iron, and sharpened several times a year. The blade is made of iron, while the handle is made of wood and can be easily replaced.

DARATI

This darati can be used for harvesting larger crops, such as corn. It can also be used to cut thin branches from trees. The darati pictured below is made from iron, increasing the durability of the tool.

6

DARATI

This darati is used for harvesting smaller crops , such as wheat and bajra. It may also be used as a weed removing tool. Operation requires the user to pull the blade towards their body in small, quick strokes. This tool's handle is made of wood, while its head is made of a thin iron blade.

DRILL PRESS

Many Mandi farmers have access to electric drill presses. This is a machine that is used by a local tool maker in manufacturing and repair of various items for local resale. The presence of this tool offers insight into the adaptability of farmers in Mandi.

7

GENTI (SMALL)

This small genti is used to hand-till the ground, disturbing the soil. This makes it easier to plant small crops, such as garlic. In comparison to the larger genti, this tool is predominately used in small gardens.

GRASS CUTTER

This machine is human-powered and used to cut grass into small pieces. It operates by pushing the grass forward with a spring mechanism as the dual-blade setup is turned. These grass clippings are then used to feed farm animals such as oxen, cows, etc.

8

THRESHER

This less traditional machine is representative of the innovations farmers have access to and have tried to implement regionally. This expensive machine was found on a farm located in the flat lands south of Mandi, and could not be used in most other locations. Threshers such as this can be driven by Petrol/Diesel or electricity.

PLOW BLADE

A plow blade is used to till the ground to make it softer and ready to plant seeds. This is a piece from an Ox-driven plow set up. It is made from iron and iron alloys, and must be continually sharpened to maintain functionality.

POWER TILLER

This is a moderately advanced replacement to the genti, a smaller version of the tractor/plow set up. It is used to till the ground, but is much more disruptive to the soil. It is run by petrol/diesel. Unlike a tractor and plow, this can be used on smaller fields, though transportation onto smaller, higher terraces can prove difficult.

PESTICIDES SPRAYER

This pesticide sprayer was found on vegetable farm in Mandi District. This device is spreads pesticides among a variety of crops, ideally at a standard flow rate. This moderately -advanced technology illustrates an inclination amongst traditional farmers to incorporate slightly more advanced farming methods.

10

OX-DRIVEN PLOW

This is a major farming tool in the Mandi region. It is used to till the ground before sowing. The plow has two major parts, the wooden frame to be kept on the shoulders of oxen, and the iron blades to break the soil.

TRACTOR AND PLOW

A tractor and plow is a mechanical way to till the ground before sowing. It is driven by petrol/diesel and contains complex parts. Attached to the back of the tractor is a plow which is made of sharp iron blades. This expensive technology was only found in the flat southern regions, on larger than average farms.

11

PANJA

The panja is used to displace and dig soil or rocks, in a similar fashion as a rake. It is used after the soil has been tilled. Operation involves the user pulling the bladed portion towards themselves. The handle is wooden and ranges from 0.5 to 1 meter long. To promote durability and functionality, the head is constructed of iron.

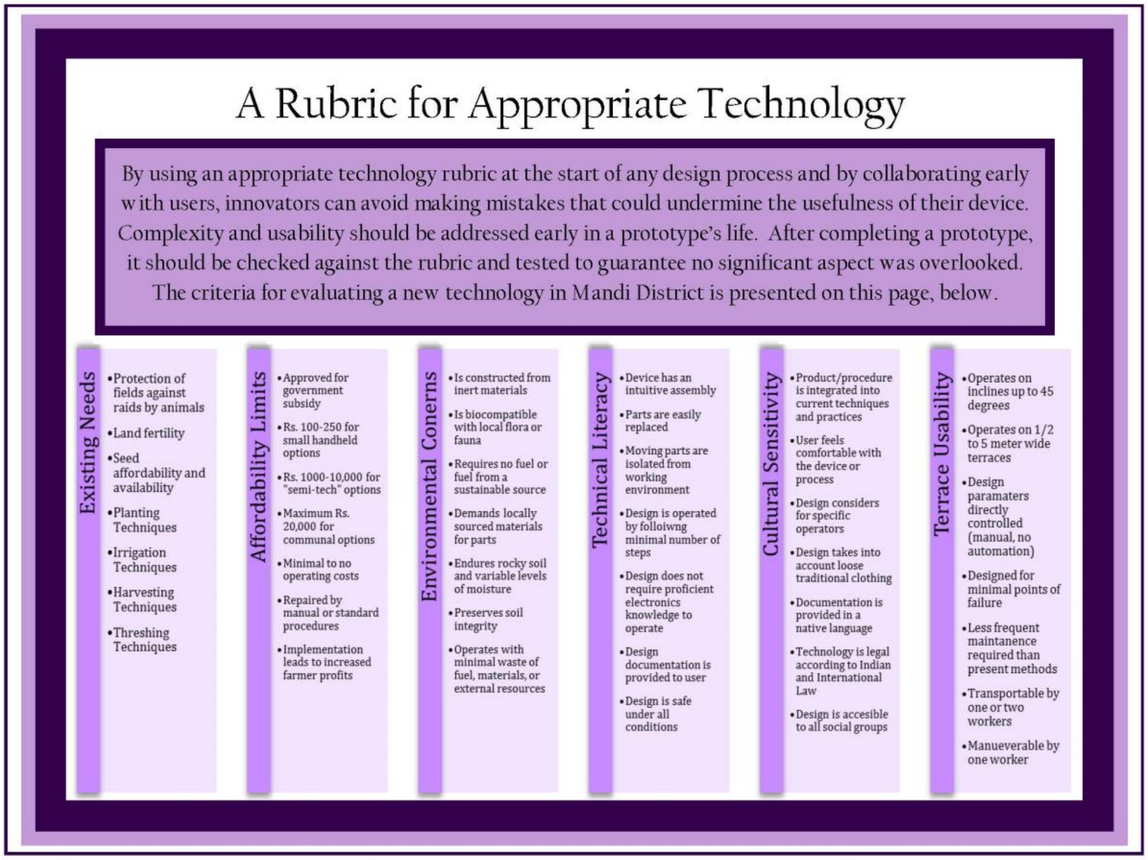
KILANI

The kilani is used to remove weeds from gardens and fields. Its head is made from iron, while its handle is generally made from wood. This tool is easily operated by men, women, and children and is key in local weeding practices.

12

The majority of farmers in Mandi District operate terraced farms, cultivating step-like outcrops carved from the sloped hills dominating local landscape. The locations of these terraces can range from steep, formidable hillsides to more hospitable valley floors. There is no standard shape, height, or width for an average terrace as each depends on the terrain, tools, and the specific farmer who originally created the terraces. Terraced land is traditionally passed down through a family, with the same land available for use across several generations. Farming on such terraces involves primarily manual labor with a variety of traditional tools.

13


A Rubric for Appropriate Technology
By using an appropriate technology rubric at the start of any design process and by collaborating early with users, innovators can avoid making mistakes that could undermine the usefulness of their device. Complexity and usability should be addressed early in a prototype's life. After completing a prototype, it should be checked against the rubric and tested to guarantee no significant aspect was overlooked. The criteria for evaluating a new technology in Mandi District is presented on this page, below.
Existing Needs
•Protection of fields against raids by animals
•Land fertility
•Seed affordability and availability
•Planting Techniques
•Irrigation Techniques
•Harvesting Techniques
•Threshing Techniques
Affordability Limits
•Approved for government subsidy
•Rs. 100-250 for small handheld options
•Rs. 1000-10,000 for "semi-tech" options
•Maximum Rs. 20,000 for communal options
•Minimal to no operating costs
•Repaired by manual or standard procedures
•Implementation leads to increased farmer profits
Environmental Conerns
•Is constructed from inert materials
•Is biocompatible with local flora or fauna
•Requires no fuel or fuel from a sustainable source
•Demands locally sourced materials for parts
•Endures rocky soil and variable levels of moisture
•Preserves soil integrity
•Operates with minimal waste of fuel, materials, or external resources
Technical Literacy
•Device has an intuitive assembly
•Parts are easily replaced
•Moving parts are isolated from working environment
•Design is operated by folloiwng minimal number of steps
•Design does not require proficient electronics knowledge to operate
•Design documentation is provided to user
•Design is safe under all conditions
Cultural Sensitivity
•Product/procedure is integrated into current techniques and practices
•User feels comfortable with the device or process
•Design considers for specific operators
•Design takes into account loose traditional clothing
•Documentation is provided in a native language
•Technology is legal according to Indian and International Law
•Design is accesible to all social groups
Terrace Usability
•Operates on inclines up to 45 degrees
•Operates on 1/2 to 5 meter wide terraces
•Design paramaters directly controlled (manual, no automation)
•Designed for minimal points of failure
•Less frequent maintanence required than present methods
•Transportable by one or two workers
•Manueverable by one worker

14