AIDA Pilot Study

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Activity: Identify and Promote effective techniques of rainwater collection for irrigation purposes in Lama and Alikadam (Bandarban, CHT). R2.A4.

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Executive Summary:

The Lama-Alikadam area is characterized by a high population of indigenous groups. Household income is dependent on agriculture with 89% percent of the baseline population engaged in agriculture either has the primary cultivators or as daily laborers for other farms in the region(RIDS 2012). The traditional system of cultivation called jhum, also known as shifting cultivation, or slash and burn, has been practiced in this region for as long as memory. Due to increasing land pressure, the fallow period has been significantly reduced, so that farmers are returning to lands that have not fully recovered from the previous jhum cycle(Nath, et al. 2005). This pattern results in many of the stakeholder falling into the cycle of poverty, where increasingly intensive traditional cultivation practices result in reduced soil fertility, decreasing vigor of crops and their resulting progeny, further contributing to lower productivity, resulting in reduced wages and less food security (Samal, et al. 2005).

The winter season in Lama-Alikadam is characterized by insufficient rainfall to maintain crop productivity. This is especially apparent in the plane lands, where two production seasons are common practice. Rain water harvesting (RWH) systems have been proposed to increase productivity of dry-season agriculture. Increased productivity may lead to income development and improved food security. Rainwater Harvesting is defined as the collection and storage of rainy-season precipitation for productive purposes. Areas of collection include run-off from developed land, ephemeral streams, and hillsides (Wisser et al. 2010).

Based on the collected evidence in Lama and Alikadam the following RWH interventions are recommended. They are presented in order of priority. All proposed implementations are set to a scale that can be easily completed in one day of work. Tong Pray, construction of staggered trenches and gully plugs for an estimated cost of 13,000 Btk to cover an area 280 m^2, or roughly 7 decimals. In Gotiram, the construction of an in-field rainwater catchment would cost roughly 8,000 Btk. In Shibotoli the recommendation is for a 5% model that would cost 83,500Btk, the majority of which would go to labor costs. In Thoin Ching, a tube well should be constructed for a cost of 45,000Btk. In Gotiram, a tube well could be fixed for a price of 50,000Btk. In Varot Mahon, the existing pond that is used as the source of irrigation could be excavated to increase the capacity. The price for this intervention is not currently known do to the necessity of price sharing negotiations and variability of equipment use fees. In Shishu as temporary earth dam could be constructed for roughly 6,000Btk, although this project has the lowest priority.

Contents:

1. Literature Based Review

Rainwater Harvesting is defined as the collection and storage of rainy-season precipitation for productive purposes. Areas of collection include run-off from developed land, ephemeral streams, and hillsides (Wisser et al. 2010). The water that is captured in this system can be used as a supplemental irrigation source to stabilize and increase agriculture yields or extend the growing period into the dry-season(Moges, et al 2011). A number of methods of rainwater harvest for agriculture development have been proposed in the literature. However, there are a number of factors that can contribute to the success of a given intervention. This paper seeks to review different methods of rainwater harvest, evaluate their strengths, weaknesses, and costs (financial, labor, and maintenance), as for application to the stakeholder regions. The conclusion of this paper will result in a recommendation for a pilot study to be implemented in the targeted areas. Factoring the wealth of knowledge from academic resources, combined with on-the-ground engagement and observation, this project seeks to identify and implement the most appropriate and cost-effective rainwater harvest option.

The Lama-Alikadam area is characterized by a high population of indigenous groups. Household income is dependent on agriculture with 89% percent of the baseline population engaged in agriculture either has the primary cultivators or as daily laborers for other farms in the region(RIDS 2012). The traditional system of cultivation called jhum, also known as shifting cultivation, or slash and burn, has been practiced in this region for as long as memory. Due to increasing land pressure, the fallow period has been significantly reduced, so that farmers are returning to lands that have not fully recovered from the previous jhum cycle(Nath, et al. 2005). This pattern results in many of the stakeholder falling into the cycle of poverty, where increasingly intensive traditional cultivation practices result in reduced soil fertility, decreasing vigor of crops and their resulting progeny, further contributing to lower productivity, resulting in reduced wages and less food security (Samal, et al. 2005). By utilizing a longer fallow period and allowing for secondary succession, stakeholders could increase soil fertility, improve positive soil attributes, increase local biodiversity, and increase the productive capacity of the ecosystem (Arunachalam & Pandey, 2003). The question is how you provide incentive to break the cycle of poverty and increase the adoption of longer fallow periods?

1.1. Quantity H_20 needed

The calculation of plant water needs is a complex mathematical exercise, where the accuracy is dependent on the quality of data. Because of the complexity of this calculation, many factors must either be assumed to be constant or ignored completely. Similarly, models describing the need of water in an agriculture setting are defined by water lost from the system, so that when water lost equals water supplied there is a net balance in the system. Water loss from a system is most accurately described as evapotranspiration. This concept combines two parallel forces in the water potential flux in agriculture systems; evaporation, largely through exposed soil surfaces, and transpiration, water lost through the conductive plant tissues (Australia Department of Water, 2007). Predicting the forces associated with evapotranspiration agriculture systems have been described through use of the FAO modified Penman-Monteith equation(Allen, et al. 1998).

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where:

ET_0 reference evapotranspiration (mm day^{-1})

R_n net radiation at the crop surface (MJ m^{-2}day^{-1})

G soil heat flux density (MJ m^{-2}day^{-1})

T mean daily air temperature at 2m height (°C)

u_2 wind speed at 2m height (ms^{-1})

e_s saturation vapor pressure (kPa)

e_a actual vapor pressure (kPa)

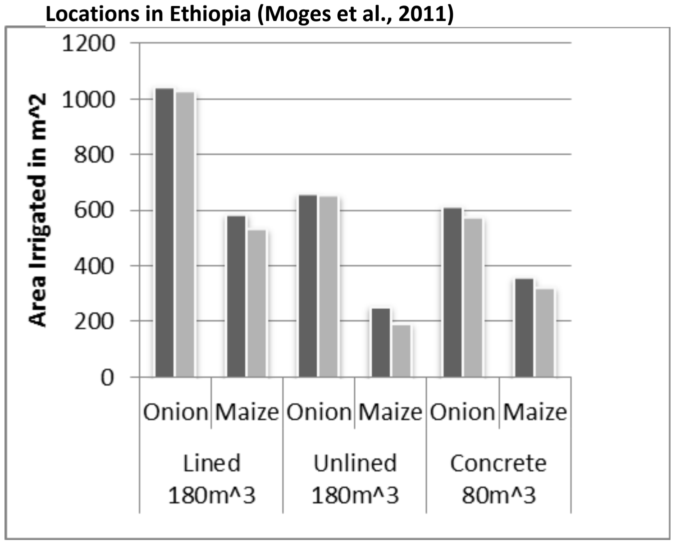
Δ slope vapour pressure curve (kPa°C^{-1})

γ psychrometric constant (kPa°C^{-1})

Many of these measurements are based on existing or predicted weather data for a given region. The calculation for evapotranspiration is based on the assumption of a reference crop (ET_0) with an assumed crop height of 0.12 m, a fixed surface resistance of 70 sm-1 and an albedo of 0.23 (Allen et al. 1998). The incorporation of a coefficient that is specific to a crop grown in a specific region has been shown to improve the accuracy of crop water requirements estimations (Abdelhadi, et al. 2000). Further corrections to this formula must be made for irrigation efficiency and proportion of field under crop cover (Australia Department of Water, 2007) in order to truly calculate irrigation volumes for an agriculture system.

Crop reference coefficients are calculated from measured data and are not constant through the growing season. Changes to crop coefficients are based a number of factors including genetics, phenological stage of crop, whether it is an annual or perennial, estimated root zone, presence of symbioses, etc. Irrigation efficiency factors the way in which the water is applied. Simply letting the water run over the surface would not allow for infiltration in to lower layers of the soil profile. A low volume consistent flow would show a much greater efficiency to irrigate crops of any type. Many of the factors in this equation are based on the weather and climate data that may or may not be available. Despite the availability of this data, the weather cannot be controlled.

Figure 1 **Average Area Irrigated From Water Catchments at Two Locations in Ethiopia (Moges et al., 2011)**



In a study of Ethiopian farmers, Moges et al (2011), describe a synopsis of rainwater harvesting systems, with an emphasis on micro-catchment. The results of this study may be seen in *figure1*, where there is a comparison of different storage methods, across two different locations, with two different types of crops. While the average irrigated area is pictured in the figure, the study describes a wild variation in the area that may be irrigated. The difference between the maximum irrigated area and the minimum irrigated area, point to the fact that estimates to determine catchment size from cropping area are subject to theoretical as well as realistic variability. The conclusion we can determine from this article is that the greatest impact of micro-catchment technologies can be realized with a lined tank, which is used to irrigate horticulture crops. This impact may be consistent across regions and provides important evidence in support of catchment systems in other parts of the world. Still, the authors of this study did not include many of the natural systems of water catchment that can be incorporated into the cropping system.

From a developmental intervention prospective it may be more appropriate to concentrate on the factors that may be most easily controlled. Because the complexity and lack of accurate data to define the variables in equations for crop water requirements, certain studies have sought to determine water storage needs through trial and error based on different cropping systems. By intervening in the agricultural water balance, certain factors may be more vulnerable to change. For example, the introduction of a water break at the end of the hose would greatly influence the infiltration capacity of water thus improving irrigation efficiency. Building soil organic matter and maintaining a sufficient soil cover seek to improve the capacity of the soil to hold plant available water. Encouraging the cultivation of perennial crops, with expansive root systems, would help to limit dry-season vulnerabilities to drought stress. While the complexity of crop water requirements bases assumptions on data that may not be available, small steps can be taken to limit the need for exogenous irrigation inputs.

Irrigation needs represent a complex calculation and are subject to extremes of variability. While it may be unrealistic to calculate precise amounts and numbers, previous trial and error examples can indicate strategies and technologies that will offer potential in small holder farming systems. If catchments are to be used in an intervention, they should be lined with non-porous materials and the greatest impact of this system would be realized with horticultural cropping systems as opposed to agronomic systems. The impact of specific interventions may also be embellished by encouraging practices that will help to contribute to infiltration and holding of water in the agriculture system. In order to maximize the impact of an intervention for dry-season agriculture it is important to maximize attributes that will contribute to positive outcome. Thereby increasing the perceived importance of the system to facilitate horizontal technology transfer and practice adoption. Similarly any proposed intervention must be coupled with an education component to encourage responsible use of water and soil resources that would increase the success and likelihood of horizontal transfer of technologies.

1.2. Review of Strategies for Rainwater Harvest (RWH)

There are two basic categories of rainwater harvesting systems, structural and vegetative (Samal, et al 2005). The segregations of these two categories are very basic as they are often intertwined and mutually adopted in a small holder land management system. Structural RWH systems utilize natural or artificial materials to hold water from running out of the system. Structural systems can include earth, rocky, or plastic constructs that improve the availability of water in the system. The effect of a structural system is realized immediately after their construction is complete. The effects of vegetative RWH systems are not generally realized without the allowance of a maturation period for the vegetative material. With a combination of plants, vegetative RWH systems utilize appropriate land use practices to provide for resource conservation that may produce a saleable product as well as contributing to conservation measures that would maximize vegetative RWH system's benefit to small landholders. The ideal intervention would combine both structural and vegetative measures in order to maximize short-term benefit, while reducing maintenance costs while instigating a long term benefit.

1.2.1. Structural RWH

Check dams, *percolation tanks*, and *constructed reservoirs* represent a strategy for large scale water harvest. The efficiency of these projects may not always be worth the effort, if the water is to be used for irrigation purposes alone. In a study in the Himalayan foothills of India, constructed reservoirs were used as a part of an integrated, participatory approach to environmental remediation, through RWH (Mittal & Singh, 1990). In this study, there were four constructed dams from the time period of

1976-1985, where the total cost per cubic meter of stored water ranged from 0.78 Rps to 19.46 Rps. Based on inflationary factors, the current costs of projects like this are likely to be significantly more, thereby reducing the cost: benefit efficiency even further. For large constructions, such as dams and reservoirs, government approval may also be necessary. In some developing regions, this could further hamper development efforts utilizing these strategies. It is the opinion of this author that check dams, percolation tanks, and constructed reservoirs are strategies that do not fall within the scope of this project.

Domestic RWH systems are a popular method of conservation in many regions of the world because they can be outfitted to the fit the needs of a locality.

Roof catchment systems utilize existing structures to divert the rainwater into an adjacent catchment or cistern. The water from these systems can then be used in the garden or for other grey-water purposes. The obstacle to the development of this technology lies in its demand for equipment. First there must be pipes connecting the gutter system of the structure to the catchment area. Within the catchment area, a diversion pipe and filter system are necessary to make sure the catchment area remains free of debris. The actual catchment structure is often a storage cistern made of plastic or cement. Roof catchment systems can be adapted to areas where there is not a roof, but still maintains an impermeable surface. Areas such as roadways and parking lots, offer a surface that could be used to divert rain water into collection vessels, however this may also increase maintenance costs with greater need for filtration.

Temporary catchment systems are another form of domestic RWH that may be more easily constructed and maintained as a developmental intervention. Through this technology, one constructs a diversion region out of an impermeable material such as a cover tarp. The tarp is physically supported in such a way that the rainwater is diverted into a storage catchment. This is a low-cost, adaptable technology that can be easily transported to different locations, depending on the materials used. This technology is also very appealing in areas where space may be a limiting factor because the system can be taken down very easily. The only downside lies in the usefulness of these materials, such as the tarp and storage tanks, that could be easily sold or used for other purposes that would reduce their useful life as a RWH device.

A recent public works program in India utilized a number of RWH technologies and techniques to provide a working opportunity for those afflicted with poverty, while seeking to improve environmental quality of areas devastated by intensive agriculture production systems(Samal et al., 2005).This report details specific technologies that are of greater use, depending on the topography. Previously mentioned strategies are primarily confined to flatland or inside the village.

Upland, structural RWH technologies seek to mediate soil erosion, diversify the land used to reduce vulnerabilities, thereby enhancing family income with conservation, in addition to enhancing rainwater percolation to improve soil water holding capacity and reducing runoff(Samal et al., 2005). Upland production systems are characterized by a slope greater than 8%. In many areas within the CHT, there is evidence of intensified cultivation systems triggering landslides, which may endanger individuals or communities.

Staggered trenches work in a manner that is similar to terraces. The staggered trenches differ from the terraces in that they are often easier and cheaper to build and maintain. In this method of *in situ* RWH, small trenches are excavated across the slope face. When the rain water, running off the steep slope, will strike the trench and begin to infiltrate into the soil. In order to construct a staggered trench, start at the ridgeline. Locate trenches directly below one another in alternate rows. Place the excavated soil on the down-hill side of the trench, creating a bund. While dimensions of the trenches can be adapted to the local conditions, Samal, et al (2005), suggest a 6ft x. 2ft trench that is 1ft deep. The integrity of the trench is maintained by vegetative material between the trenches and planting the created bund with grasses.

Gully plugs are another useful upland, RWH strategy. This strategy collects soil and water in the normal zones of high-velocity runoff, thereby reducing its velocity and mitigating soil erosion. A gully plugs are constructed in series along the gully, to change the drastically sloping zone into a series of flat beds. The basis of the gully plug begins with a 1ft trench, dug into the hill slope. Within this small trench make a barrier using large, local stones. The barrier is constructed to a height that will allow for water to pass, in times of serious precipitation, over the barrier, while remaining in the gully. The gully plug technology is a low cost strategy that targets specific areas to remediate run-off. In the application of this technology it is imperative to select a suitable topographic region.

Based on the geologic formation of a given region, the steep slopes that are adjacent to the ridge line begin to mellow, creating an upland region with a slope less than 3%. Based on the changes in topography, the methods of water harvesting must be adapted. Typically, upland fields with a slope of less than 3% are ideal candidates for water harvesting catchments.

Rainwater catchments are tanks (plastic or cement), lined ponds, or unlined ponds that are constructed in a natural depression of the agriculture field. This technology utilizes the natural topography to divert and collect excess rainwater in both the adjacent field, but as well as the surrounding topography. This system is very similar to the previously mentioned domestic catchment systems, except that they are built in the field, adjacent to the area where the water will be used. To construct the rainwater catchment system, the initial site selection is imperative. Excavate an area that is at the low-point of the field. The excavated soil is placed on the down-hill side so that this side is significantly higher than the up-hill side. Depending on the soil type, a liner must be installed to prevent seepage. A liner is an impermeable material that is used to cover the surface before the pond is filled. The liner acts like to protection to prevent water from seeping out of the system. In heavy clay soils a liner will not be necessary, once the soil particle size becomes larger, seepage may be an issue. The size of the catchment is dependent on the area of cultivation. Please refer to previous sections when determining the size of the catchment.

Dug wells are another useful method to acquire irrigation water in the dry season. While not RWH, *per se*, this technology has the ability to capture sub-surface seepage, that may be lifted or moved to the agricultural fields (Samal et al., 2005). While on paper, this sounds like a good idea, dug wells are hindered by the uncertainty of prevailing hydrology. If there is not water in the subsurface soil layers, then this very costly option can be a great waste of money.

The 30 x 40 model was proposed by Samal, et al(2005) as a method to capture rainwater in field with a mild slope, between 3% and 8%. This method divides the field into separate plots roughly 30ft (along the slope) x 40ft (across the slope). At the lowest point of each plot a small catchment is excavated. The excavated soil is used to create a bund, which delineates the plot's area. The bunds can be planted with grasses, and the plots are cultivated in horticulture crops. This strategy is useful in rainwater harvest because it breaks the velocity of water, so that it does not achieve the velocity at which erosion would occur. This strategy also allows to the harvest of runoff and allows it to percolate the soil, improving the water holding capacity of the soil and the growth of the plants.

Excavation tanks are used to tap the sub-surface water. This strategy can be used in plane lands to access water resources during the dry season. There are two variations, on the central theme of excavation tanks, proposed by Samal, et al such as the 5% model and lowland tanks (2005). These systems are similar to the previously reviewed catchments, except that excavation tanks seek to harvest the sub-surface flow, where the catchment tanks are constructed to harvest surface flow. In the 5% model, the field plots are demarcated based on topography and 5% of the total area is excavated to form a water catchment. The 5% excavations are to be evenly spaced through the field site, so that adjacent catchments can be used to irrigate adjacent fields. Lowland tanks are dug at the topographically lowest point in the field site. During the monsoon season, this strategy will act as a surface water catchment, however during the dry season this strategy can be used to utilize the sub-surface flow of water. The 5% model is suitable for a patch with unidirectional slope where the crop fails due to regular water stress. The patch should have good soil cover with moderate porosity. The norm for allocating 5% area is not sacrosanct. One needs to consider land qualities and farmers' preferences and other crop plans. A bigger pit is required to store more water. While laying out the pits in successive plots along the slope, one needs to make sure that the pits are rather staggered and not in a straight line(Samal et al., 2005).

Figure 2 **Lowland Excavation Tank (Samal et al., 2005)**

Structural methods of RWH span from low cost, simple projects, to high cost public work projects, needing government approval. The technology that is used should be suited for the topography of the stakeholder region. By using the appropriate technology for the appropriate topography, we can improve the likelihood of uptake among the beneficiaries. For certain RWH technologies, such as gully plugs, staggered trenches, the 30 x 40 model, and certain types of rainwater catchment, the technologies are not meant to be permanent but rather to create suitable conditions for vegetative strategies to take over. It is in this way that maintenance costs, to the physical structure, may be mitigated. With appropriate plant selection and planting strategy, certain structural RWH techniques may be able to usher in long term benefit to the stakeholder region.

1.2.2. Vegetative RWH

Agroforestry is a cultivation system that seeks to create a diverse, productive, profitable, healthy and sustainable land use system (USDA National Agroforestry Center, 2008). Agroforestry essentially entails the incorporation of perennial crops with annuals and/or animals on the same land parcel. This land use system has been identified as a mechanism for rural economic development, mediate the effects of forestland degradation, and provide a model for sustainable land use (Alam,et al 2009 & Nath, et al2005). Other studies have found Agroforestry to be a superior land-use system when compared to the jhum system in the Chittagong Hill Tracts of Bangladesh in particularities such as Benefit to Cost ratios, net present value calculations, and on return to labor (Rasul & Thapa, 2006). Despite the promise of agroforestry, several obstacles to adoption still remain. Insecure land tenure, complicated transit routes, double levy on agriculture commodities, and the farmer's poor socio-economic position where all identified as reasons obstacles for the adoption of agroforestry practices

(Rasul & Thapa, 2006). Still one of the greatest problems may be the lack of recognition as many farmers simply cultivate in a diversified manner, without identifying as agroforestry. *Appendix 2* presents common understory fruit and vegetable plants as well as their common companion tree species from the Thakurgaon District, in the North West corner of Bangladesh(Zaman, et al 2010).

Vegetative strategies for RWH incorporate the principals of agroforestry. Similarly many of the vegetative practices are meant to compliment certain structural practices. Just as many of the structural RWH techniques are specific to certain topography, so are the vegetative techniques. The different categories of topography are divided in three sections, greater than 8% slope, between 3% and 8% slope, and less than 3% slope.

For the land with the most severe slope Samal, et al(2005) suggest the incorporation of timber trees and perennial grasses. The trees are planted on a very tight spacing into the staggered trench construction. One plant is placed between the trench and the excavated soil, while the next one is planted in between the two trenches. This document suggests a 6ft staggered planting, although realistically, 8 to 12ft spacing may be more realistic. Areas that are not in cultivation with the trees are planted in grass, so that the grasses will come on quick and stabilize the soil while the trees grow to maturity. Timber plants are suggested in this phase because they do not require as much attention as some other horticulture crops. Still, this zone could easily be planted in fruit trees in addition to timber species.

As the slope starts to even out and the obstacles of cultivation become less and less. It is suggested that with slopes declining to about 3% farmers can begin to incorporate more horticulture crops such as annual vegetables, in addition to tree fruits. Also this region opens up cultivation to pulses. Lowland (<3% slope) follows the same pattern with an increasing planting density of more high value crops that require more attention with a shorter turnover.

Vegetative strategies to encourage rainwater harvesting are important because the plants can hold the soil in place, while contributing organic material to the soil, which improves the water holding capacity. The lowest cost interventions will require the incorporation for vegetative material to prevent the need for continued maintenance. When selecting plant species to use for vegetative methods of RWH, it is imperative to engage the beneficiaries as they generally have a better sense of the local flora as well as prevailing market conditions. Their decision should be steered towards tree crops with staggered gestations as well as annual plants that may provide complimentary benefit, such as legumes. For example, Banana plants will produce a saleable crop in 1 season, but then will no longer be productive after 4 or 5 seasons, when they are cut down and incorporated into the jhum system. Mangoes, on the other hand, require a 6 to 7 year gestation, but will then remain productive for up to 50 years. In conclusion, to maintain the productivity of lands and continued adoption of sustainable practices, it is necessary to carefully planned integration of annuals and perennials, woody and herbaceous, that reflects stakeholder engagement, while providing benefit for as long as possible and as quickly as possible.

2. Review of Existing Situation to Identify Needs

The Lama-Alikadam area is characterized by a high population of indigenous groups. Household income is dependent on agriculture with 89% percent of the baseline population engaged in agriculture either has the primary cultivators or as daily laborers for other farms in the region(RIDS 2012). The traditional system of cultivation called jhum, but also known as shifting cultivation, or slash and burn, has been practiced in this region for as long as memory. Historically, this system involves the cutting and burning of plant material in the dry season, generally from December to April. The deposition of plant material improves soil fertility so that the land can be cultivated for several years, beginning with annual crops and slowly rotating to perennial crops, such as tree fruit. The cultivation system generally last for several years, then it is left fallow to allow the system to recover. However the sustainability of this system is threatened by increasing populations densities, from endogenous growth, but also emigration, so that indigenous groups have lost access to large tracts of land (Nath et al., 2005). The lack of land availability has forced the indigenous groups to shorten the rotation of their jhum systems, returning to fallow lands sooner, before the fertility has been restored. Shortening the rotations has resulted in inhibition of secondary forest succession (and bio-diversity), loss of soil fertility due to erosion, and increased water pollution(Nath et al., 2005). According to the baseline data 44% of families are involved in jhum cultivation systems (RIDS 2012).

Jhum cultivation is not the only production paradigm of the targeted stakeholder region. Furthermore, the jhum system is inactive during the winter months. As a result, the plane land cultivation systems can provide a significant resource in preventing seasonal lapses in food security. The winter months are characterized as receiving minimal rainfall to the point where surface water sources are extremely reduced. As a coping strategy, many of the plane land cultivators will utilize different strategies to cope with the lack of water. In our interviews with stakeholders (*See Appendix 1* for full detail), most villages recognized the promise of temporary dams and excavation tanks. Other villages indicated that neither temporary dams nor excavation tanks were effective in their particular plane land fields and that they could nor practice plane land agriculture in the dry season because of this lack of water.

The identified needs vary between villages based on the current situation. For some villages with flat land access, the priority is to improve the area under cultivation during the winter season. For those villages that do not have plane land access, the needs become a little more complex, with a need for integrated soil management practices that increase productivity of steeply sloping lands while mitigating natural resource depletion. Despite exogenous insight into current situations, it is necessary for the stakeholders to understand the problems in order to appreciate intervention, and adopt the solutions.

3. Recommendations for Intervention Based on Identified Needs

3.1. Tong Pray

This village is characterized by its remote location and steeply sloping topography. The access to this village is a treacherous slope that bears the mark of erosion. This primary transportation route would significantly inhibit access to markets. In this interview, stakeholders said that rice was the primary source of both income and calories consumed for this village because it can be saved for several months. Therefore, increasing productivity of the severely sloping lands that characterize this region would help to contribute greater economic return, increase available food, and hopefully contributing to stakeholder livelihood. The use of mixed vegetative and structural interventions could help to achieve these goals and with the incorporation of perennials, could also promote greater dietary diversity.

Because the Village of Tong Pray practices the jhum system, rather exclusively, any intervention should be timed with the early stages of juhm establishment, or the time period between December and April, when the stakeholders are preparing the field. Because of the varying topographic features of this region, it will be important for agriculture officers and local stakeholders to come together to determine the appropriate strategies for their respective location. With this understanding a mix of upland structural RWH strategies, such as **staggered trenches and gully plugs**, should be utilized with a combination of longer lived perennial plants such as citrus, papaya, and mango, to insure villagers will receive benefit, while maintaining permanent soil cover. The local rice plants can be used as the grass to stabilize the bunds.

Despite the agricultural concentration of this project, this village expressed significant concerns about the quality of their drinking water. Future activity in this region may explore the potential of tube well installation. However, based on the elevation; aquifers for may be too deep for tube wells to access.

3.2. Gotiram

3.2.1.

This village has made unsuccessful attempts at implementing dry-season cropping systems, with limited success primarily due to lack of water resources. As result of limited economic opportunities during the dry season, the stakeholders turn to firewood collection as their primary method of income generation. Creating the availability of agriculture income generating activities will help to provide opportunity that would limit the necessity of deforestation, associated with firewood collection.

The field that is used for flat land cultivation is too far from the consistent surface water source. There is a perennial stream that runs through the plot. The prevailing soil type is very heavy clay, so liners may be unnecessary. Similarly, the proposed intervention site is close to 2km from the closest access road. Any intervention must rely on tools and materials that are easily transported by hand.

The proposed solution for this village would be a **rainwater catchment** to store the rainwater from the perennial stream, for use during the dry season. This village spoke of previous attempts at excavation tanks that were unsuccessful. Therefore, the surface water catchment seems to be the most appropriate strategy. According to estimates from the Moges (2011) model, a lined catchment of 183m ^{3} would provide enough irrigation for just over 1000m^2 of agriculture land in Ethiopia. The field of interest in Gotiram has roughly an area of 200m^2, making the estimated size catchment tank needed roughly

$36m^3$. According to this estimate, with dimensions of three meters on each side would provide sufficient water for the dry-season irrigation needs. The use of an unlined catchment, which may serve as the more conservative estimate, even in catchments with a lining, would require a somewhat bigger tank. Where the Moges study (2011) estimates an area of roughly $650m^2$ would be irrigated using a tank of $183m^3$. Based on this estimation and unlined tank would need to be roughly $55m^3$. Despite the aesthetic appeal of an evenly cubed catchment structure, the catchment tank should be as deep as possible to avoid evaporation.

3.2.2.

Gotiram also has a tube well in their village. The **tube well** is in a partial state of functionality. The majority of the water leaks from the tube at some point below the soil surface so that only a portion of the water, under very little pressure, comes out of the tube head. This village has made attempts to have the tube well repaired, to no avail. The technical aspects of fixing this well are beyond the villagers and they estimate that it would take 50,000 Btk for a contractor to fix the well. If this tube well were functioning it would not only provide clean drinking water to the village, but may also provide irrigation water to homestead gardening activities.

3.3. Shishu

This cultivation system for this village is predominantly a later succession jhum that supports mixed perennial cultivation system. The trees are mature and bearing quite nicely. This village has small amount of flat land which is most likely dedicated to tobacco in the winter season. This village may be a good candidate for more advanced agricultural training, such as market development of their fruits. Topography would lend itself in one area to a **temporary dam**, however this is a shared creek and arrangements need to be made with the neighboring villages.

3.4. Thoin Ching

Villagers remarked that homestead garden production is hampered by a lack of water in the dry season. Based on this statement a roof catchment system or temporary constructed catchment system would be able to prevent the obstacle of limited irrigation water. The problem is that, in their focus group, the villagers described several water related problems, including a lack of safe drinking water. Therefore, homestead garden irrigation may not be the primary issue of this village and any intervention for home gardens would be diverted to drinking water uses. The installation or remediation of the tube well may serve both the needs of the homestead gardeners, while providing safe drinking water for the villagers. The villagers suggested that the well was not deep enough and this was the reason that there was no water coming out. Therefore it is the recommendation that another **tube well** should be installed.

3.5. Shebatoli.

This village boasts a balanced mix of jhum and plane land agriculture with 17 families engaged in jhum and 13 families engaged in plane land agriculture. Most of the plane lands are close enough to the river that they are able to use a motorized pump to apply irrigation water. There is one holding pond that is used by this village, through an informal agreement with a Bangaldeshi family; the villagers of

Shebatoli will use this pond, for free, as an intermediary holding pond during the dry season. The water will be pumped from the river to this holding pond, where it will be used as irrigation water. The focus group did mention that one of the fields, of 400 decimal in size, was still too far from the holding pond to receive irrigation during the dry-season. It was difficult to determine if all of their plane land fields made an area of 400 decimals, or if the one field that does not receive dry-season irrigation measures 400 decimals. The focus group suggested the idea of building another pond in this area, however, they determined that they would need a very large pond for their irrigation needs and has determined it to be too expensive.

Based on the size of the agricultural field the implementation of the **5% model** would be most appropriate.

3.6. Varot Mohan-Nursery

This nursery is operated by local stakeholders in the AIDA-Torongo beneficiary network. Project managers complain that the water source, a nearby pond, may not be sufficient for dry-season irrigation of nursery crops. As a result, the **pond excavation** was considered as a justifiable solution. Because the costs for use of excavation equipment are not known, it is the recommendation of this consultant that measures instead be focused on water conservation by following Best Management Practices for container production systems. Still, cost sharing measures may be negotiated with local landowners that would subsidize and reduce the cost the AIDA-Tarango partnership would incur in order to justify the excavation.

4. Budget for Proposed Intervention

4.1. Tong Pray- Staggered Trenches/Gully Plugs

		Unit Cost	# needed	Total Cost	Notes
Labor		250/day	5	1250	
Skilled		500	1	500	
Materials	Trees	100	100	10000	Mango
Labor and material total				11750	
	Hand tools	350	5	1750	
Sub-Total				13500Btk	

One Unit in this budget calculation covers and are of 16.5m^2 and uses 6 trees. A Project with 100 trees will cover an area of 275m^2 or roughly 7 decimals. To The cost to scale this project to a 75 decimal size would cost **$128000.**

4.2. Gotiram

Gotiram 1-Rainwater Catchment

		Unit Cost	# needed	Total Cost	Notes
Labor		250/day	5	1250	
Materials	liners	250	8	2000	1 liner =4.5m2
	Hand tools	350	5	1750	
Maintenance		250	12	3000	1 day / month
Total				**8000Btk**	

Gotiram 2- **50,000Btk**

Well Maintenance

This price is based on an estimate from villagers during a focus group. This price is roughly the cost of a new tube well. Therefore this may be an over-estimate for fixing an already existing tube well.

4.3. Shishu-Temporary Dam

Unit Cost			# needed	Total Cost	Notes
Labor	Day Labor	250/day	10	2500	
	Tarango Labor	???	3		negotiations with neighboring villages
Materials	Hand tools	350	10	3500	
Total				**6000Btk**	

4.4. Thoin Ching

Estimated costs of a new tube well construction are estimated to be **45,000 Btk** (Ahmed, 2002)

4.5. Shebatoli

According to Samal, et. al (Samal et al., 2005) the cost for constructing the 5% model would cost roughly 200 Btk per decimal. This cost only includes labor, and not the necessary hand tools, so the cost for this intervention could be estimated at just over 80,000Btk. This number would depend on the local water needs and prevailing topography. Generally speaking, one demarcation could be prepared per day, so the number of days and the time needed would depend on the number of demarcated plots, thus impacting total cost. Based on current evidence 80,000 Btk plus the cost of 10 hand tools, 3500 Btk, would be an appropriate estimate for total intervention costs, 83,500Btk.

4.6. Varot Mahon Nursery

Suggest use of hydraulic excavator to make the pond deeper. Estimated costs are difficult to determine because of the necessity for cost-sharing arrangements with landowners as well as the price variability for this type of work

5. Prioritized list of Proposed Interventions with maintenance recommendations

5.1. Tong Pray

This village is perhaps the most food and nutrition insecure area we visited. This dietary insecurity is matched with a pattern of environmental degradation from shortened jhum rotations. This village receives top priority in order to promote interventions that would improve soil fertility and agricultural productivity, while incorporating different crops in pursuant of dietary diversity.

Maintenance:

It will be important to make sure newly planted trees receive at least 1 inch of water per week. This can come in the form of rainwater or irrigation. When irrigating new trees, be sure to apply water slowly to ensure infiltration into soil profile.

5.2. Gotiram 1

During the dry season the villagers of Gotiram practice fire-wood collection and harvest. This practice involves felling living trees, or collecting previously deceased wood material. The material is collected for the purpose of fuel. Because of increasing rates of deforestation, the villagers are forced to search further and further from their home. In order to develop income generating activities that are closer to home and do not rely on deforestation practices, it is the view of this consult that this intervention should receive priority.

Maintenance:

Regular maintenance will be necessary to insure the catchment remains free from debris and other materials. The catchment could easily fill with sediment. Therefore every month it will be necessary to clean the bottom of the catchment to remove any debris or sediment that may have fallen in.

5.3. Shebatoli

This is one of the larger villages in the sample group. By promoting a small catchment pond, this project has the potential to cultivate horizontal transfer within the village. Similarly, due to the reliance on agriculture, this village would significantly benefit from the increase dry-season productivity.

Maintenance:

Regular maintenance will be necessary to insure the catchment remains free from debris and other materials. The catchment could easily fill with sediment. Therefore every month it will be necessary to clean the bottom of the catchment to remove any debris or sediment that may have fallen in.

5.4. Thoin Ching

Drinking water access is a significant health issue for this community. Any intervention for agriculture irrigation would likely be diverted to drinking water purposes. Therefore in order to satisfy the needs of both agriculture irrigation and drinking water a tube-well deserves priority in this village

Maintenance:

It may be necessary to check the tube well to make sure there is no contamination with arsenic.

5.5. Gotiram 2

In the village there is a tube well that is not functioning properly. Because this tube well does not directly relate to agriculture irrigation, this intervention project receives relatively low priority. Still, the estimated price of 50,000 Btk may be an over estimate and with the cost-effective proposals previously mentioned on the list, there may be funds leftover for these repairs.

Maintenance:

It may be necessary to check the tube well to make sure there is no contamination with arsenic.

5.6. Varot Mohan Nursery

The land for which the proposed intervention lies is owned by a private, third party. Any capital improvements made to this area should be combined with cost sharing measures so that the AIDA-Tarango partnership does not bear the entire cost of improving another party's land. This intervention is listed at the end so that any left over money, which will most likely not cover all costs associated with this project, would be used to develop a cost-sharing relationship with landowner.

Maintenance:

Continued observation to identify sources of siltation will be necessary to maintain proposed excavation efforts.

5.7. Shishu

The necessity of rainwater collection for this village is very low. Any intervention in this region would be an expression of good-will, but likely nothing more. The flat land that is cultivated in this village is quite small and the jhum gardens are quite productive. Although apparent costs are low and appropriate intervention would require negotiation with neighboring villages for land-sharing arrangements.

Maintenance:

For temporary dam, little maintenance is needed. Just be sure to keep people and livestock from walking on the surface. For more permanent structures regular inspection may be necessary to insure that there are no leaks or holes that could compromise the integrity of the project.

6. Conclusion

Horizontal transfer of agriculture knowledge is best mediated through farmer networks (Neill & Lee, 2001). This can be captured in extension efforts through farmer field schools or other forms of participatory knowledge transfer. The ability of extension services to engage with the beneficiaries would significantly help to promote the knowledge transfer. The extension agent can promote engagement by approaching problems from a farmer's perspective, rather than purely academic. It is the opinion of this author that the more an extension agent can appear to be like 'one of the farmers' then the chances of knowledge uptake will be greater.

In a study examining IPM knowledge transfer(Ricker-Gilbert, et al. 2008), farmers in Bangladesh were likely to uptake simpler concepts through less intensive training events, such as field days. However, for more complex concepts, such as grafting and biological pest management, more intensive training sessions, such as Farmer Field Schools or repeated agent field visits, were necessary to ensure the knowledge uptake. Still, this study points to informal knowledge transfer between farmers as being very important and without adequate training it would be difficult for this avenue to be effective. Another study (Islam, et al. 2012) examined the sustainability to farmer led extension groups. The building blocks for the sustainability of these efforts hinges on varying ideas of capital. Financial capital is devised through micro-credit, institutional capital is devised through internal governance, human capital through appropriate group facilitation, and social capital is devised through trust and respect between members. All of these factors combine to ensure the lasting success of farmer led extension activities. As extension service providers it is our duty to promote these forms of capital through beneficiary empowerment.

Rainwater harvesting techniques can be similarly transferred through official and unofficial extension methods. The key to promoting widespread adoption is to first determine the appropriate technology, through engagement with beneficiaries. Just because the technology is appropriate does not mean it will be adopted by beneficiaries. It is important that everyone involved understands the reasoning and objectives or intervention projects. Only through integrated education efforts will be able to promote sustainability and efficient technology transfer.

Implementation Perspectives:

Strategies were proposed for implementation, however, stakeholder acceptance varied among localities. The discovery of sub-surface water flow in Gotiram allowed the construction of a low-land excavation tank, rather than the proposed in-ground catchment. In Tong Pray, after facilitating knowledge transfer with another Mro village, the stakeholders agreed to construct staggered trenches and gully plugs in the establishment of the following season's jhum. The need in Sishu was determined to be insufficient in order to justify construction costs and training. In Shebatoli, stakeholders were offered training on rainwater harvesting techniques, so that they could select their own intervention. Intervention in Thoin Ching was cancelled because recommendations were based on inaccurate evidence that overestimated need. The recommendation for pond excavation n Varot Mahon was rescinded due to a lack of stakeholder agreement, in addition to the realization that the nursery would be moving within 3 years.

General Comments:

The relationship with the local implementing parties represents the bridge with which to connect to stakeholders. The cultivation of knowledge and appropriate relationships with the local facilitation parties cannot be underestimated. Therefore the thorough training of knowledge distribution agents is an objective of top priority. Similarly, local implementing agents may have personalities or perspectives that represent major obstacles for the efficient implementation of development goals. The willingness to try and the openness to new ideas are desirable characteristics for local cooperating agents. While experience and seniority in development initiatives are generally considered positive attributes, they may also contribute to the ego of those agents, creating difficult conditions to conduct, design, and implement development activities.

As the relationship with the local cooperating partners must be cultivated, so must the relationship with the targeted stakeholders. Single, independent meetings are not sufficient to gauge the situation in a single village. It is not even clear if multiple visits are sufficient in developing intervention strategies. Common practice, especially in agriculture, is difficult to change. The true change must be identified and implemented by stakeholders, in order to create a lasting effect. Engagement with stakeholders is difficult and takes time and in order to solicit participation, they must be included in the decision making process. Which is much easier said than done.

Specific Village Comments:

<u>Gotiram</u>

Stakeholder follow up on October 9 resulted in selection of construction site for in-ground catchment. Labor terms were agreed and construction began the next day. During construction the sides of the catchment were constructed at 90 degree angle so that they were perpendicular to the ground surface. This did not provide the necessary support for the walls and resulted in significant sloughing. To counter this obstacle, stakeholders constructed walls on a 45 degree slope. Construction site was also in the path of sub-surface water flow. As a result the catchment began to fill with water; up to three feet, two weeks after construction began. As a result of the significant sub-surface water flow, the implementation strategy was adjusted to an excavation tank, at least temporarily. The water that is currently in the excavation tank will be used for this dry season, then if it dries up construction will be continued with the objective of constructing an in-ground catchment.

<u>Shibotoli</u>

October 10 visit to this village was characterized by poor planning. Upon our arrival it was clear that no preparation had been made on the part of local implementing agents at TARANGO. We could not locate the original targeted field and made preliminary agreements with another farmer/field, despite the fact that need in this area was limited.

In a consecutive visit on October 15, the 5% model was proposed to the whole village in a community meeting. The stakeholders did not like the strategy and requested that we educate them on all the potential strategies so that they could pick the most appropriate technology.

As a result on November 3, the agriculture officer had a sharing meeting with the community where he shared the 5 different techniques proposed for rainwater harvesting in Lama and Alikadam. The community identified 3 sites where they think in-ground catchment should work, so now final identification and implementation steps need to be taken.

<u>Thoin Ching</u>

Original interview identified a mix of drinking water and home-garden irrigation issues. In the interviews, consensus was that the village did not even have access to drinking water in the winter and that any water harvested through intervention would be immediately directed to human consumption. This is why proposed intervention reflected necessity of clean drinking water that could additionally be used for home-garden irrigation i.e tube well construction. Follow up interview suggested that original data collected may not have been accurate. In this village there was one tube-well and two partially functioning ring-wells. Drinking water issues did not seem immediate or as big of an issue as previously suggested.

Tong Pray

October 10 visit from single cooperating agent discussed implementation of gully plugs. However, it was difficult to determine actual results of this meeting. The result of this meeting is a proposed agreement to begin construction on October 15. At this point it does not seem clear that cooperating agent nor stakeholders have a clear idea of proposed intervention.

October 16 visit was characterized by significant confusion. Another agreement was made for the gully plug intervention, where the stakeholders only agreed to contribute labor to transport the stones that would be used as a building material for the plugs. The staggered trench portion of the intervention was included as an afterthought. While everyone agreed to the proposed interventions, the Karbari, or village leader, kept asking about a fish pond, suggesting that he might not have a proper idea of proposed objectives. This meeting was concluded by labor negotiations.

A knowledge exchange was established with the current stakeholders and the Mro community that is adjacent to the Shishu land holdings. The Mro community is currently practicing proposed interventions with success. So, this example was used to educate the Tong Pray stakeholders on the strategy we are trying to suggest. In this way were able to facilitate a more meaningful learning moment that not only came from other farmers, but those of the same indigenous ethnicity. Following the visit to the other Mro community, the stakeholders of Tong Pray offered three different areas where the interventions may be implemented, so that the local implementing agents could select the most appropriate area. The same was selected on November 5, and agreement was reached to start working in January, when the land will be ready to be cultivated.

Shishu

When presented with the proposed intervention, stakeholders mentioned that this approach had already been tried, unsuccessfully. They suggest using stronger materials. This intervention relies on the cooperation a neighboring Mro community. The landowner of the adjacent parcel was present at the meeting. Stakeholder suggests running pipes from an up-stream reservoir.

Consecutive meetings reveled that reservoirs do not contain sufficient volume to supply crop water needs. Furthermore the needs of this village may not justify the construction of a dam in any form. The adjacent Mro village was identified as a potential training partner for the Tong Pray Mro community.

Varot Mahon

October 17 community meeting, with pond owner resulted in significant negotiations and little agreement. However, following the 2 hour long meeting it was realized that the nursery will be moving 2 km down the road, making pond excavation pointless. Therefore this intervention opportunity was rescinded based on lack of need.

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Appendix 1: Notes from field visits

These are rough notes collected from field visits. They are supplied in this report in accordance with section 4 of ToR 'Reporting and Delivery'

9/18- Murung (Bangla)/ Mro Villages

Tong Pray - 12 year old village

Cultivate Mango, Banana, Chicken, and Pig in Juhm style of production. The focus groups said that everything else is just juhm and does not identify it as an independent production system. But other crops produced in this region were Rice, vegetables, sweet pumpkin, ginger, potato, bean leaf; pretty much everything except for salt and oil. It was difficult to pinpoint, but the participants in the FG seemed to indicate that products went to market first, and then what was not sold was left for the family to consume.

The Juhm production system, also known as shifting cultivation, consists of three slash and burn phases from December to April. Around April, the first rains of the monsoon season begin as does the seeding for that season's crops. The seeds that are planted consist of both annual and perennial crops. The annual crops are harvested throughout the season, while the perennial crops continue to mature for the next season. Following the productive period for the annuals crops, they are cleared to make space for additional, *ad hoc*, vegetative growth. The period for productive perennial systems lasts as long as the crop remains productive. For bananas, this could be as little as 5 years, or for papaya, 3 years, or for up to 40-50 years for a mango production system. The crops that they grow are in accordance with the production system they have known for generations and follow a successional pattern. Still, April is left as the most food-insecure month.

During the April – June time period many members of the village will try to take day-laborer positions in the local village. In the past season, three of sixteen families were able to grow enough food to save for the offseason. Only rice was saved, no horticultural crops. The most productive crop in terms of economic return and calories consumed is the highland rice. This rice is a varietal that is saved from season to season. The members of this village will often use fertilizers or pesticide, spending upwards of 2000Btk on products that were recommended by the shopkeeper. Although the organization that provides aid to this village offers free pest management advice, this was not utilized by this village.

The Juhm production systems rely on rain to feed their production systems. Nobody uses irrigation, nor have they thought about installing a tube well. The main source of water is a surface creek that runs nearby the village. However, this is often contaminated and there are many cases per year of diseases like cholera, typhoid, and chronic diarrhea.

****Use agroforestry concepts to prevent erosion on steep sloped juhm fields****

Amtoli Chak Nam

This village practices winter Horticulture in the flat lands with tradition juhm in the highlands. Generally, this village will use water from the river to irrigate their crops. However, in the dry season, the river will dry up. To fix this situation, this village will dig a hole in the middle of their field, where water is usually found 5-6ft below the ground level. If the location with water and the agriculture field do not correspond, then the villagers will install a small tank, to store water in the field, as a middle point, to apply as irrigation.

Bangla Village Nearby Mong-Shue-Prue

It is an interesting concept in the CHT, the indigenous people mainly inhabit the hilly areas while Banglas seem to have laid claim to the flatlands. This trend dates back as the source of conflict between the indigenous tribes of the Hill Tract regions and the government of Bangladesh. Based, on the peace accord signed in 1997 between these two parties, the indigenous people were supposed to gain more land and control over the areas in the CHT region. The government of Bangladesh has done everything possible to skirt this agreement and maintains the people of Bangla origin are the appropriate inhabitants of these lands. The impact of this emigration is that the indigenous people do not have enough land to complete the necessary ecological cycles of the jhum production system.

In this day, we were able to visit a flat land village, with Bangla inhabitants that had been the subject of previous government charity. The government of Bangladesh built an earth dam to contain a small stream. The resulting pond became too much, or the earth dam was not properly maintained and one day the dam broke loose and released all its contents. The local communities, who were not consulted in this public works project, were more concerned with the earth dam's role as a bridge between two villages, rather than the potential for increased irrigation. The bridge has since been mended; however the dam still ceases to function.

Varhot Morhon Nursery Ali Kaean

Nursery complains of high mortality rates. Inspection of media realizes substrate with very high clay content and internal iron reduction implicating root zone asphyxiation. Consultation with project leader, later in the evening suggested fertilizer, potash and triple super phosphate (top-dress), as interventions for plant mortality. When questioned about gleying, of iron reduction consultant indicated that this may be a symptom of disease. The consultant went to describe other methods of intervention, including poking hole in the plastic bags and preparing a liquid fertilizer drench. In my opinion, the most appropriate intervention would be to identify a cheap, locally sourced organic material and a large particle size adjunct to mix with existing clay soil substrate. Alternatives may be to mix substrate independent of native soils or solicit other nurseries in the area for advice on their container media.

9/19/12

Akiram

This village is inhabited by the Tripura ethnicity, the majority of who are currently practicing Baptists. The Baptist mission has helped to support schools, buildings, and other infrastructure improvements. This was a very large village, with close to 60 families living here. One way that makes identification of Akiram women easy, is that they will wear one necklace per year of age. As these necklaces are often a status symbol, the women will embellish the number of necklaces they are wearing.

In Tripura twenty families are engaged in flatland agriculture and thirty families are engaged in jhum. Some of the products that are grown in both jhum and flat land agriculture include potato, gourd, ack, sweet melon, ginger, and rice. The varieties, especially for rice, will vary between the two production paradigms. The jhum agriculture does not receive irrigation, relying solely on the rain. The flat land farms receive irrigation from that is pulled from the river, using a motor pump. In the dry season the river may be too dry, in which case they will dig a hole in their field and be able to access the water table. Some people in the village also have a pond that is used for aquaculture, after which the water will be used for irrigation.

December to April are the times when the villagers will need irrigation water the most. The most food insecure time periods are from June to August, while the crops are maturing, but before they first crops are harvested. This previous year, around three families experienced food shortages.

The village wants 2-3 tube wells, another pond.

Complain that many rainwater harvesting systems are too expensive.

The farmers of this village generally irrigate their crops for 2 hours every three days during the dry season.

We observed an ordered planting of fruit trees on the upland.

Gotiram

10 families farm the plain land

- Rice
- Ginger
- *Shakh shobji*
- potato

20 families practice jhum

- Rice
- Tomato
- Vegetables

This village has tried to grow food during the dry season, but it did not work, due to a lack of water. Because of the inability to cultivate food in the dry-season, there is no income being generated for this village, during this time. As an alternative income generating activity, this village has begun firewood collection and harvest. If water were available, they would be more likely to cultivate produce during the dry season. Limitations to irrigation in this region include lack of access to surface water and because their flatland is somewhat upland, they cannot transport water to these fields due to lack of a pump.

Deep Tube Well (Ring Well):

Government project (to build ring wells)
Has not worked for five months
Talked with the chairman, no results
Received visit from contractor, but cannot afford services to fix well (approx. BTk 50,000)
Never received hand pump
The pump worked for about three weeks

Water is leaking out of the tube at some point underground. We witnessed a slight trickle of water coming from the top, but significantly more water coming from where the tube meets the soil.

The field for this village is very farm from the village, but we will visit them another day.

*****this seems like it would be a good village to perform some water saving intervention*****

Durjodon

34 households in this village
5-6 families cultivate plain land
5 families cultivate jhum
The rest of the families (24) are engaged in daily labor.
Rice is the only product that is cultivated in the plain land and they rely completely on rainwater to irrigate the rice. There are two ring wells in this village, although one is not working. The villagers believe that the broken tube well has water, as it is 50ft deep, but they didn’t seem to know why there was no water coming out. The village was not interested in fixing the broken tube well because they have a functioning one 20ft away.

During the dry season, the villagers try accessing irrigation water by digging holes in the field. However, they were not ever able to find any water. The fields are of scattered locations, with some being nearby while others lie at a considerable distance from the village. If water were available to these farm lands, the village could improve productivity on roughly 40 decimals of land.

Manikjon

Most people here do not have land. The main source of income is working in other people’s Juhm fields. Ten families in this village have plain land that they use to grow rice, although they will be switching to tobacco in the coming dry season.

-Timeout-

Tobacco Cultivation

This is an interesting phenomenon in rural Bangladesh, but especially in the CHT. Two tobacco companies exist in Bangladesh, the Bangladesh Tobacco Company and the British American Tobacco Company. These companies will provide small plants for the farmers, give the farmers pesticides and fertilizers, they will even buy the product at the beginning of the season. This has resulted in a number of farmers adopting tobacco cultivation as a source of income generation. The only problem is that tobacco is a very heavy feeder, depleting the soil of fertility in a matter of years. This key fact, of course, is omitted by the tobacco companies, so the farmers continue to adopt the practice. In this case, the government claims not to have anything to do with the practice of tobacco cultivation. However there are a series of very serious permits that are necessary for tobacco cultivation. The permit process is so serious that only two companies have actually successfully received a permit….

-Time in-

Vegetables are the dominate product in the jhum system. This village is very close to a river that flows all year long. So, providing the crops with irrigation is rarely an issue. In the most extreme instances of irrigation water scarcity, the villagers will prepare a small, temporary, earthen dam, in order to store water for a few days.

9/20/12

Extension Office Visit; Tube well Engineer

The government provides ring well to villages in the Lama region. The Engineer complained that the villagers do not perform maintenance on the wells. They say that the office is always available to offer technical support, but it is rare that the villagers ask for it. The District Engineer, who is in charge of the project, is in Bandarban.

Krishi Officer

This officer has only been in the region for one month. He has heard of a few rainwater harvesting options. For example some people will construct a rubber or semi-rubber dam. Other villagers, with the help of NGOs, have constructed a large dam. The *krishi* officer pointed to one potential project that would benefit from the construction of a large dam. This project would cost 10 *crore* and would serve ten families. One other suggestion from the *krishi* officer was to build a platform with a storage tank on top. The villagers could move the water from a tube well or other source, and pump this water to their fields. This is the common model that provides water to the government's and other buildings. There have been a few models that suggest harvesting rain-water from the roof.

This was described as the entirety of the *krishi* Officer's knowledge on the subject, although the office suggested we look up the Rural Development Academy of Bangladesh and the Northwest Crop Diversification Project.

Babu

This is an 81 family village, where roughly 50% perform jhum agriculture and 5 families perform flatland agriculture. The other families work as daily laborers. The same vegetables are cultivate in the jhum and the flatland, with the exception that banana and mango are cultivated in the jhum fields. In this village there is always surface water from the river for all the flatlands.

Jhum agriculture is only performed in the rainy season. Even in the rainy season there can be water problems, either too much or too little.

One villager suggested that, if perennials were given timely irrigation that they would come into maturity sooner. The villagers would like to irrigate their jhum system, but it is too expensive to pump water from the river.

Bottoli

This village is right next to the river. There are 22 families in the village where 8 cultivate jhum, and 9 cultivate flatland. The other families work as daily laborers on other farms. This village cultivates the usual crops that include; rice, chili, cucumber, mango, banana, orange, tobacco, spinach, and begun. This village does not grow jhum vegetables in the dry season. There is surface water access all year long, predominantly from the river. Bananas last for 3-4 years. Mango trees can last up to 50. The jhum fields are roughly 1-2 hours away, walking and the average land parcel is about 200 decimals.

Shishu=>Bangla Shish=> Marma

There are 19 families in this village and 5 have participated in a farmer training. 5 families cultivate in the jhum system while no one cultivates in the flat land. The flat land surrounding the villages was sold to some Bengali. All of the families, except those in jhum, are engaged in daily labor. The different crops grown by this village are grown in different fields, without integration. During the off season, when they are not cultivating jhum, the villagers are working in someone's tobacco field. Some families will also lease out their land for others to cultivate rice.

While working as day laborers on other farms, the villagers can earn 150-200Btk for women and 250-300Btk for men per day. The days are ten hours each and lunch is not included in the wage.

This village mentioned that they would like to grow vegetables in the dry season, if water were available, because then they would not have to work has day laborers. Many of the villagers were sitting on a blanket made of old rice bags. This looks like a promising material for a pond liner that would cost 250Btk for a piece roughly 5ftx10ft.

Seems to be good candidate for a lined pond in the jhum field

Thoin Ching

There are 72 families in this village. 20-30 families participate in jhum and 20-30 farm the flatland, all others work in daily labor on nearby farms. In and around this village potato, peanut, bitter melon, okra, rice, and eggplant are all popular vegetables to cultivate. In the jhum system, the villagers will also cultivate banana, papaya, sweet-fruit (?), and mango. In the winter season this village will cultivate tobacco and other vegetables, including parsnips.

There is a fairly large river that runs nearby the village, so there is not usually any need for supplemental irrigation water. The villagers will use a submersion pump to move the water from the river to the fields. Some of the farmers also have a pond that can be used for irrigation.

Several members of the village have home gardens. Some will be able to produce vegetables for 1 season and some will be able to produce vegetables for two seasons in the year. Irrigation water was identified as a main initiation for those who can only cultivate home gardens for one season.

32 families have home gardens. The main objective of these gardens is to provide food for the household. Sometimes they are able to produce enough food so that they can take the extra produce to the market. While there are problems with the vegetables no receiving enough water in the dry-season, the villagers point to the absence to a tube well as the main reason. They said the an NGO installed a tube well a while back, but it only worked for a short period of time. They say the well only goes 80 ft, but it really needs to go 200ft. There is also a need for toilets and clean drinking water

While this may be an option, to provide rainwater harvesting for home gardens, the villagers did not seem to take to this idea. Therefore, while the need exists, promoting adoption may be difficult.

1 decimal = 40.42m^2

Gainda

There are 10 families in this village. Four practice jhum and 6 farm the plane land. Some of the main agriculture products in this village are rice, *shigun* (a tree used for timber), and several different vegetables. Six months out of the year, the jhum system requires attention. Most of the agricultural area of this village is in the plain land, so many families will work in both the jhum system and the plain land. There is a very large river that runs nearby the village, so water for irrigation is rarely a problem. The jhum system is too far from the river, but production during the dry season is very unusual for the jhum area.

Headman Para

The flatland is cultivated for two seasons while jhum is only cultivated for one season. Some of the products from this village include tomatoes and other vegetables. The village is able to pump water from the river, using a motor pump that they rent from a neighbor. The pump costs Btk160/hr to rent. This village also has a tube-well that is 146' deep.

22 women from this village have received farmer training. This village was having trouble growing their jhum rice, so they have stopped. Currently, this village produces bananas, mango, shigun and other vegetables in the jhum system. There are not problems with water in the dry season because the villagers will construct temporary dams out of earth. The dams are constructed nearby the fields, so the water may be transported by hand.

Lama Nursery

Big compost pile in E side of nursery. The compost pile was made using a layer of soul, a layer of plant material, then mixing in TSP (*trisodium phosphate*). The agricultural specialist here recommends letting the pile sit for three months before using.**This seems like any normal composting operation, except for the use of TSP. Phosphate is not a limiting nutrient in the compost pile and does not seem to have a true role in this system. Instead suggest the use of an organic nitrogen source, such as manure, or if it is not possible should use a NITROGEN source, not phosphorous.**

The nursery presents a western exposure, with plant rows running north to south. The plants are very close to each other, with the pots touching each other, despite crowded canopies. 'This is the system' the workers replied when asked about the tight spacing. There were also any earthworms growing around the nursery site. One of the workers mentioned that they usually grow under the banana tree. **this would be a wonderful source of nutrients**. When asked about the roles of fertilizers in plant physiology the agricultural specialist said, "We use fertilizer to make the plants strong, MOP controls disease and makes roots strong and the urea makes the leaves green"

Gotiram revisited

**See notebook sketch for detailed drawing…
100' x ~30' with a six foot rise opening to a northern exposure. A perennial water source runs along the west side of the plot with three terraces in the middle. The entire plot is surrounded by a fairly steep slope, except to the east, which is roughly 3-4ft step.

Choto Bomo

Twenty five families are in this village where 5 practice jhum and 20 farm the plane land. This village is able to pull off three seasons of rice and one season of tobacco. It appears as if they are including the nursery stage of seedlings in the season calculation. This village also grows veggies. The jhum system consists of 1 season where they grow banana, mango, and papaya. When there is not sufficient water in the field, the villagers will pump water from a temporary pond that they have made by building an earth dam. All seeds for production are purchased in the market.

The *Krishi* officer has made a few visits to this region. He will usually come to demo a new technology or planting style. He has helped this village plant trees around their pond.

9/23

<u>Mara Kola</u>

All the families of this village are engaged in agriculture, both jhum and flatland. While 3 families own the majority of the land, the rest of the 24 families in the village will rent the land. There are number of different crops produced in this region including rice, *shigun*, banana, pineapple, and mango. The latter if which are the tree species from the jhum system. Vegetables include tomato, potato, sweet gourd, and tobacco. jhum does not have any problems with water, mainly because there is nothing cultivated in the dry season. In the flatland the village does not usually run out of water, but if there is problem it usually only with a few families and they can rent a pump to move water to their field.

<u>Shishu Para-field visit</u>

Mixed perennial system of guava, ginger, oranges, mango, papaya. The land being cultivated in this *baghan* system is roughly 1000 decimals. The garden slopes around the hollow, but has a roughly E exposure. The most appropriate intervention for this group would probably be a next level training course, such as marketing or other advanced production techniques. This village has a very small amount of flatland. The creek that runs near the flat land could be dammed very easily, especially in one spot where the banks are very close to each other. However, this would require negotiation with the neighboring village and the benefit may not necessarily outweigh the cost of the work.

Would be interesting candidate, however, may not have a very high priority

<u>Mong Shue Prue</u>

There are 45 families in the village, 10 families in jhum, and 5 families in flatland. The rest of the families are engaged in daily labor on other farms. The wages of daily laborers is roughly Btk150 for women and Btk250 for men. The work day is about 9 hours with an hour break for lunch. This village performs a rice/veggie rotation where rice is grown in the wet season and the veggies are grown in the wet season. When the village is faced with water shortages, they will pump water from the river to make up for the deficiencies. Some people, whose plots are very far from the river, will pump water to an intermediary holding pond. Usually rain is the only uncertainty in their system as they provide plenty of irrigation and fertilizer.

<u>Shebatoli</u>

There are 37 families in the village, 17 practice jhum, 13 farm the plane land, and the remaining 7 work as day laborers. Members of this village will perform a rice/tobacco rotation. Most of the farmlands are near the river. The lands that are further from the river are also on a significant slope, where jhum is practiced. When the flatland begins to dry up in the winter, this village will pump water from the river, usually into a holding pond that is owned by some Bengalis. The pond is under an informal agreement and no rent is required. There is one portion of flat land that is too far from the river and holding pond to be reached with this irrigation water. When asked why they don’t build a pond to irrigate this region and bring it into production for the winter season, they said that the cost would be too much. According to the villagers estimates a pond of 30’x30’ that is 10-12ft deep would cost 1lac

Btk20,000. In the jhum system, some people who have money, will plant a more permanent garden (assume because they can afford the plant material?)

400 decimal of plane land with no irrigation (?)
***This could be a good candidate for the construction of a small pond**

There is also a broken tube well in this village. This well employs the use of plastic pipe to move the water from another location. The villagers believe that the pipe is broken at some point along the way. They went on to question the quality of the water from the originating source because they believe it has made people sick.

Appendix 2: Plant Species of Interest

- The introduction of perennial varities of common grasses/legumes would be very useful. Examples would be perennial rice or peanut.

Companion Planting recommendations from Thakurgaon District, Bangladesh (Zaman et al., 2010)

Tree Species	Vegetables Grown Under Trees		Creeper Vegetables Grown Using Tress as Trellis	
	Major	Minor	Major	Minor
Mango	Arum, amaranth, spinach. Turmeric, country bean	Ginger, corolla, cow pea	Sponge gourd, ribbed gourd	corolla
Jackfruit	Sweet gourd, pineapple, chili, turmeric, arum	Indian spinach, re spinach, cowpea	Sponge gourd, ribbed gourd	Country bean
Coconut	Amaranth, arum, spinach, turmeric, radish	Pineapple, eggplant, ginger		Sponge gourd, betel leaf
Jujube	Amaranth, chili	Spinach, turmeric	Country bean	Sweet gourd
Banana	Red spinach, garlic	potato	Betel leaf	Sponge gourd
Litchi	Eggplant, radish	Amaranth, radish, pineapple, spinach		cucumber
Mahogany	spinach	Amaranth, ginger		Country bean
Sisso	Turmeric, amaranth	Eggplant, arum	Sweet gourd	Ribbed gourd
Guava	Pineapple, ginger	garlic	Sweet gourd, country bean	Bitter gourd

Tree Species from of Homes gardens in Thakurgaon District, Bangladesh (Zaman et al., 2010)

Local Species Name	**Scientific Name**	**Local Species Name**	**Scientific Name**
Horticultural Species		**Forest Species**	
Mango	*Magnifera indica*	Mahogany	*Swietenia mahogany*
Jackfruit	*Artocarpus heterophylus*	Neem	*Azadirachta indica*
Banana	*Musa spp.*	Sisso	*Dalbergia sissoo*
Jujube	*Ziziphus mauritiana*	Karoi	*Albizia procera*
Guava	*Psidium guajava*	Raintree	*Samania saman*
Litchi	*Litchi chinensis*	Kadam	*Anthocephallus chinensis*
Bael	*Aegle mermelos*	Shimul	*Gossypium harbacium*
Coconut	*Cocos nucifera*	Tarul	*Albizia chinensis*
Pomelo	*Citrus grandis*	Jiga	*Trema orientalis*
Papaya	*Carica papaya*	Eucalyptus	*Eucalyptus camaidulensis*
Jalpai	*Elaocarpus floribunds*	Khoksha	*Ficus hispida*
Lebu	*Citrus limon*	Mander	*Erythrina variegate*
Bamboo	*Bamabusa*	Pitrai	*Aphanamixis polystachya*
Betel Nut	*Areca catechu*	Shonalu	*Cassia fistula*

BEST MANAGEMENT PRACTICES FOR CONTAINER-GROWN PLANTS

Source: Southern Nurserymen's Association Publication,
Best Management Practices: A Guide for Producing
Container-Grown Plants, 1997
Regulatory Citation; COMAR 15.20.08.07B
http://aggie-horticulture.tamu.edu/syllabi/431/bmp.html

Growing plants in containers is a unique production system compared to growing plants in field soil. Container plants are grown in substrates that contain a limited amount of water, retain small quantities of nutrients and confine roots in a limited volume. Consequently, production inputs such as irrigation and fertilization require precise and properly timed applications in quantities that result in maximum benefit to the container plant production system. Thus, the opportunity exists to make sure the best possible management strategies or Best Management Practices (BMPs) are used, recognizing the site-specific nature of nursery production facilities. BMPs include operating procedures and practices to control site runoff which can result in the discharge of nutrients and pollutants to the waters of the State.

When preparing a nutrient management plan for an out-of-ground operation, a nutrient management consultant must conduct an Environmental Risk Assessment which is described in Section II-D of this manual. The purpose is to evaluate the potential risk to the environment of nutrient movement from these out-of-ground growing areas. If the potential risk is medium or high, BMPs shall be utilized to minimize risk. A selection made from the best management practices described below shall be recommended and utilized in accordance with their applicability to site conditions when required for reducing risk of nutrient movement. BMPs not listed here may also be used if they serve the same purpose to reduce risk.

This Guide includes two parts. Part I includes Container Irrigation Management Practices and Part 2 addresses Container Nutrition Management Practices. Under the subheadings in each part are specific best management practices that are marked with a bullet (•). These are meant as a supplement to the text and a quick guide to commonly used best management practices for container operations.

Part I: Container Irrigation Management Practices

Introduction

Irrigation is a very important aspect of plant production since fertilizer and pesticide runoff are related to irrigation practices. Irrigation efficiency can be expressed relative to three aspects of water application: 1. uniformity of application; 2. amount of water retained within the substrate following irrigation; and 3. for overhead irrigation, the amount of water that enters containers compared to that which falls between containers. Irrigation application efficiency will be addressed relative to irrigation system design and management. While some irrigation systems are more efficient than others, it is important to realize that poor management of a relatively efficient system can greatly reduce or negate system efficiency and increase pollutant discharge to runoff or percolating waters.

Methods of Application

During the growing season most nurseries irrigate on a daily basis in which the daily water allotment is applied in a single application (continuously). An alternative to continuous irrigation is cyclic irrigation in which the daily water allotment is applied in more than one application with timed intervals between applications.

• Cyclic irrigation is used to decrease the amount of water and nutrients exiting the container.
• Periodically check the nozzle orifice for wear or plugging.
• Install a backflow prevention valve at the water source or pump
• Recycle nutrient-laden irrigation water used in sub-irrigation systems to prevent discharge of contaminants to the environment.

Irrigation Application Amount
• A substrate's absorption capacity is related to the pre-irrigation substrate water content. The wetter a substrate is, the less water it will hold, so adjust the daily irrigation volume according to the substrate water content in order to minimize leaching.
Irrigation Water Quality Irrigation water quality is the most critical factor for production of container-grown nursery plants. Poor water quality applied with overhead irrigation can result in damage to foliage, change substrate pH, or result in unsightly foliar residues or stains.
Use of poor quality water in irrigation systems can clog mist nozzles and micro-irrigation emitters. Irrigation, fertilization and pesticide efficacy are more easily managed when using good quality water. To ensure the use of water with desirable qualities, monitor the irrigation water constituents. Monitor water quality at least twice a year (summer and winter). However, more frequent monitoring is needed to alter production practices in response to changes in water quality.
Use of reclaimed water, runoff water or recycled water may require some reconditioning since disease organisms, soluble salts and traces of organic chemicals may be present. Water quality should be tested to ensure that the concentration of chemical constituents is acceptable for plant growth. If so, the risk of concentrating pollutants that may be discharged to surface or ground water is minimized.
• Monitor irrigation water quality to ensure pollutants are not discharged.
Management #Strategies for Water Conservation
• Use rain shutoff devices to prevent irrigation system operation and minimize nutrient runoff.
• Collect irrigation and rain runoff and use for irrigation.
• Manage irrigation runoff to minimize the possibility of nutrient laden water polluting surface or ground waters.

Runoff Water Management
Erosion is the process by which the land surface is worn away by the action of water, wind, ice or gravity. Water flowing over exposed soil picks up detached soil particles and debris that may possess chemicals harmful to receiving waters. As the velocity of flowing water increases, additional soil particles are detached and transported. Water flows have a tendency to concentrate, creating small channels and eventually gullies of varying widths and depths.
Sedimentation is the process where soil particles settle out of suspension as the velocity of water decreases. The larger and heavier particles — sand and gravel — settle out more rapidly than fine silt and clay particles. It is difficult to totally eliminate the transportation of these fine particles even with the most effective erosion control program. Container nurseries are especially susceptible to erosion during times of new development and prior to filling empty container beds.
• Develop a plan for erosion and sediment control for each container nursery.
• Seed, sod or stabilize in some manner newly constructed or barren areas to prevent erosion and sediment loss.
• Address unsuitable site-specific topographical characteristics before establishment of vegetation.
• Use temporary vegetation when bare areas will exist for 30 days or longer.
• Use permanent vegetative establishment to stabilize disturbed areas and reduce erosion and sediment loss.
• Use mulch to control erosion on disturbed land prior to vegetation establishment.

• Use erosion control blankets or netting to hold mulch in place as necessary during vegetation establishment.

• Use filter strips to prevent erosion.

• Use ground covers to provide a means of erosion and sediment control on slopes where mowing is not feasible
or grass establishment is difficult.

Collection Basins

Use of collection basins may be a primary means of reducing water quality problems. The goal of each operation is to prevent irrigation water from leaving the property. Evaluation of each site will determine if collection basins are necessary or possible.

During the irrigation season, to the maximum extent practicable, all irrigation return flows should be recirculated with no discharge back to public waters. As a general rule, design newly constructed water collection and recycling facilities to accommodate the irrigation return flow. If irrigation return flow is used for another irrigation practice not associated with the container nursery, it is considered equivalent to recirculation, provided no discharge to public waters occurs.

Construct collection basins with clay-like materials with good scaling characteristics or line them with an acceptable membrane liner. Construct these basins with an emergency overflow to prevent dike damage in the event of overtopping. Basins or other structures must have all necessary state and local permits prior to construction. When rainwater is allowed to discharge from the property, it must be considered in the design of the water collection basin.

• Collection basins are a primary means for reducing the potential of chemical laden water leaving the container nursery site.

• If rainwater is discharged from the property, it must be considered in the design of the collection basin.

• Design collection basins to collect about 90 percent of the applied irrigation water.

Grassed Waterways

A grassed waterway is a natural or constructed channel; shaped or graded to required dimensions and established with suitable vegetation for the stable conveyance of runoff. This practice is used to reduce erosion in a concentrated flow area, such as in a gully or in temporary gullies. It is also used to reduce the amount of sediment and substances delivered to collection basins, nearby waterways or sensitive areas. Vegetation may act as a filter in removing some of the sediment delivered to the waterway, although this is not the primary function of a grassed waterway. Do not use grassed waterways as travel lanes. Maintain vegetation to prevent erosion and control runoff.

• Grassed waterways provide for the uniform movement of water resulting in reduced sediment and other substances delivered to collection basins.

• Do not use grassed waterways as travel lanes; maintain vegetation.

• Use lined waterways to direct concentrated flows of water to collection basins.

• Use lined waterways reduce erosion in concentrated flow areas.

Management of Stormwater

Stormwater runoff is water flowing over the land, during and immediately following a rainstorm. On site storage of stormwater can reduce peak runoff rates, provide for settling and dissipation of pollutants, lower the probability of downstream flooding, stream erosion and sedimentation, and provide water for other beneficial uses. Never discharge stormwater runoff into surface or ground waters. Route runoff over a longer distance, through grassed waterways, wetlands, vegetative buffers and other places designed to increase overland flow. These components increase infiltration and evaporation, allow suspended solids to settle and remove potential pollutants before they are introduced to other water sources.

Whenever possible, construct the components of the stormwater management system on the contour following the topography. This will minimize erosion and stabilization problems caused by excessive velocities. It will also slow the runoff allowing for greater infiltration and filtering. If the components of stormwater are not constructed on the contour, the components must be stabilized to prevent erosion. Other methods to stabilize the components of stormwater management include the outlet terraces and grade stabilization structures.

- Stormwater management minimizes erosion.
- Treat agricultural wastewater with wetlands designed and managed for that purpose.

Part 2: Container Nutrition Management Practices

Container Substrates

Many terms including soil, media, soilless media, medium, potting or container mixes, and substrates are used to describe potting materials for growing plants. However, many of these terms are imprecise or confusing. Container mixes or potting mixes imply that more than one component is used in potting and growing plants. The term “substrate” avoids much of the confusion of other terms and is descriptive of the entire composition. Substrate is the term used in Europe and most other parts of the world to describe the components of the root rhizosphere within containers.

- Choose components of container substrates that are best adapted to plants and management.
- Recommended physical characteristic values for nursery container substrates after irrigation and drainage are (percent of volume): Total porosity 50 to 85 percent; Air space 10 to 30 percent; Container capacity 45 to 65 percent; Available water content 25 to 35 percent; Unavailable water content 25 to 35 percent and Bulk Density 0.19-0.70 g/cc. A substrate with a high proportion of coarse particles has a high air space and a relatively low water holding capacity. Consequently, leaching of pesticides and nutrients is likely to occur.
- Apply micronutrient amendments according to manufacturer’s recommendations listed on the product label.

Fertilizer Applications

There are a number of acceptable methods to achieve fertilization of container-grown plants. During the growing season fertilization can be accomplished by one or more applications of a controlled-release fertilizer. One method is to apply a fertilizer solution through the irrigation system with the frequency of application dependent on nutrient concentration in the substrate solution. CAUTION: when fertilizer is injected in the overhead irrigation system, steps shall be taken to address the nutrient loading of the water leaving your property, because much of the water from overhead irrigation systems falls between containers. Fertilizing through irrigation water is appropriate for low-volume irrigation systems in which irrigation water is delivered to the container. Even then, care shall be taken to minimize leaching from the container to prevent nutrient laden runoff from entering surface or ground water.

- Apply fertilizer only when needed. Use a fertilizer nutrient ratio of approximately 3:1:2, N:P205:K20.

Controlled Release Fertilizer

Controlled-release fertilizers may supply essential plant nutrients for an extended period of time (months). Fertilizers are available that contain different mechanisms of nutrient release and different components.

- Amend the growth substrate prior to potting with controlled-release fertilizer rather than applying fertilizer to the substrate surface if containers are subject to blow over. Mix controlled-release fertilizers uniformly throughout the growth substrate.
- Do not broadcast fertilizer on spaced containers.
- Nutrients in the substrate solution can be leached regardless of the type of fertilizer applied, making irrigation management important.

Superphosphate

Phosphorus leaches rapidly from a soilless container substrate. Complete controlled-release fertilizers applied during the growing season should supply adequate phosphorus.

• Do not add superphosphate to the container substrate.

Application Rate

Controlled-release fertilizer application rates vary from product to product, but also depend on species and container size. The goal of a fertilizer program is to apply the least amount of fertilizer for the desired growth so that nutrient leaching is minimized.

• Apply controlled-release fertilizers at the manufacturer's recommended rate. Reapply fertilizer when substrate solution status is below desirable levels.

• Application rates for fall and winter (after first frost) or when using subirrigation, are usually one half the rates used in summer.

Supplemental Fertilization

• Accomplish supplemental fertilization or reapplication by injecting fertilizer into irrigation water or, placing fertilizer on the surface of container substrate.

• If injection is used with overhead irrigation systems, runoff must be collected or steps taken to address nutrient loading of water leaving your property.

• Inject an individual element or a combination of elements in concentrations slightly less than desirable levels to be maintained in the growth substrate.

• Surface-applied fertilizer should be applied to small blocks or groups of plants, thus minimizing nutrient loss and nutrient loading of runoff water

• Avoid broadcast fertilizer applications unless containers are jammed together.

• Record fertilizer product name and analysis, date and location applied, and general notes about plant and environmental conditions. Use past records for troubleshooting current problems.

• Group plants according to their fertilizer needs so supplemental fertilizer applications can be made onl to plants requiring additional fertilizer. This is particularly important if fertilizer is injected in irrigation water.

Monitoring Container Substrate Nutrient Status

Environmental conditions influence the longevity of fertilizer release. Thus, to ensure adequate nutrient levels in the growth substrate, monitor the container substrate nutrient status and use the results to determine fertilizer reapplication frequency, ensuring that desired levels are maintained. Periodic monitoring is important because excessive or inadequate nutritional levels may not be expressed by visual symptoms, although growth is reduced. High concentrations of nutrients can result from substrate components, inadequate irrigation frequency and duration, water source, and/or fertilizer materials and application methods. Container substrate nutritional levels may also accumulate during the overwintering of plants in polyhouses. Excessive nutrient concentrations injure roots, ultimately restricting water and nutrient uptake. Conversely, rainfall and excessive irrigation can leach nutrients from the container substrate resulting in inadequate nutritional levels and threaten water quality. Substrate used for long-term crops should be tested at least monthly, but biweekly monitoring during the summer may be necessary to track fluctuations in electrical conductivity (EC) which is used as a relative indicator of the nutritional status of the container substrate. Even when controlled-release fertilizers are used, substrate nutritional levels will gradually fall during the growing season to levels that may not support optimal growth.

High temperatures in overwintering structures can result in nutrient release from controlled-release fertilizers. Monitor substrate electrical conductivity two or three times during the winter to ensure levels are not toxic.

• During the growing season, monitor container substrates every 2 to 4 weeks.

• During the winter, monitor substrate electrical conductivity two or three times.

• Collect several representative substrate samples to ensure that samples represent the growth substrate being considered.

Interpretation of Substrate Extract Levels

Most fertilizers (except urea) are salts and when fertilizers are in solution they conduct electricity. Thus, the electrical conductivity of a substrate solution is indicative of the fertilizer level that is available to plant roots.

• Desirable container substrate electrical conductivity levels are 0.5 to 1.0 mmhos/cm for solution fertilizer only or the combined use of controlled-release and solution fertilizer. Desirable container substrate electrical conductivity levels are 0.2 to 0.5 mmhos/cm for the use of controlled-release fertilizer only. Ranges given in Table I correspond to most container-grown landscape plants; however, adjustments must be made for plants known to be sensitive to fertilizer additions.

• Plants with a low nutrient requirement may grow adequately with nutrient levels lower than those given in Table I.

• Measure the irrigation water electrical conductivity. The irrigation water electrical conductivity will allow you to know the contribution of your water to the extracted liquid or leachate electrical conductivity and this should be considered when interpreting the substrate electrical conductivity.

Table I

Desirable nutritional levels to be maintained in the container substrate for plants with medium to high nutritional requirements. Levels are for the interpretation of the Virginia Tech Extraction Method when fertilizing with solution or liquid fertilizer alone or in combination with controlled-release (CR) fertilizer or using only controlled release-fertilizer.

	Desirable levels	Desirable levels
Analysis	Solution only or CR & solution	CR Fertilizer Only
pH	5.0 to 6.0	6.0 to 6.0
Electrical conductivity, dS/m (mmhos/cm)	0.5 to 1.0	0.2 to 0.5
Nitrate-N, NO3-N mg/L (ppm)	50 to 100	15 to 25
Phosphorus, P mg/L	10 to 15	5 to 10
Potassium, K mg/L	30 to 50	10 to 20
Calcium, Ca mg/L	20 to 40	20 to 40
Magnesium, Mg mg/L	15 to 20	15 to 20
Manganese, Mn mg/L	0.3	0.3
Iron, Fe mg/L	0.5	0.5
Zinc, Zn mg/L	0.2	0.2
Copper, Cu mg/L	0.02	0.02
Boron, B mg/L	0.05	0.05

Levels should not drop below these during periods of active growth. Plants with low nutritional requirements may grow adequately with lower nutrient levels.

Appendix 4: Rain Water harvesting and Integrated Farm Management

1. Farming Practices for water Conservation

Perennial Plants

- Identification and introduction of perennial rice varieties would be useful to jhum rice cultivation.

Perennial Plants are ones that live from year to year and do not need to be replanted. Because these plants live from year to year they can develop a large root system that will be able to search for water. It is important to provide optimal care for the plant when it is young, so that it will become a strong, healthy tree. The longer a plant lives, the more benefit it can create. A mango tree that can produce fruit for 50 years is more valuable than a Banana tree that produces for one.

Permanent soil cover

Grass, trees, shrubs, will cover the soil when it rains. When the rain falls directly on the soil it forms a layer, that the water cannot pass, called a crust. When the crust forms water will not go into to the soil. When the water does not go into the soil, it will run on top of the soil, so that erosion occurs. Erosion is the force that reduces the health of the soil. Erosion is bad because it takes the healthy soil away.

Irrigation Notes

Give water to plants early morning. This is the best time to irrigate all types of plants. To give the plant water in the middle of the day is bad. Because it will evaporate before the plant can drink it. This is another reason permanent soil cover is good. It will 'break' the water before it hits the ground. When the water breaks before it hits the ground, it will go into the soil. Also the permanent soil cover provides shade so that the water is happy and will go into the plant.

In the nursery it is not wise to have permanent soil cover. When it is not wise to have soil cover, a device to break the water must be used. Please see the picture on the right. Put this device on the end of the hose. It will make the water very small so that it can go into the soil.

Picture of Water Break

Give plants water when they are dry. Stick your finger into the soil to check the moisture. This is a useful way to determine if the plant wants water.

New plants need 1 inch of water every week. This water can come from the rain or other source

2. Strategies for Rainwater Harvest

Tanks and Ponds

These are used to store water until it is needed. The name for any storage vessel is a catchment. There are many types of catchments. A pond is one type of catchment. There are big ponds and little ponds. Big ponds are expensive. Little ponds are not expensive. Many times, it is easier to build many small ponds.

Sometimes the pond will lose water into the ground. If the pond loses too much water into the ground, build a liner. A liner is a piece of material that water cannot go through. A cement bag or a cover tarp are two examples.

A 'Gazi' tank may also be used to store water. These tanks are big. They are best to use in a home garden

Trenches

Trenches

Trenches harvest rainwater that is going down a hill. The trench makes the water slow. When the water is slow it will goes into the soil. The trench will also spread the water. This is very important in areas with steep slope. Planting trees, or other perennial plants, around the trenches will make them stronger. The trench will also make the plant because it will help to provide water. To create the trenches like the picture is very difficult. It may be easier to build smaller trenches in a staggered formation.

Gully Plug

A gully is the area where the water flows to the river. Sometimes there is a stream in the gully. Most time, in the dry season there is no stream in the gully. When there is a lot of rain, the water will move very fast in the gully. When the water moves fast, it will cause erosion. A gully plug Is built, so that the water will move slowly.

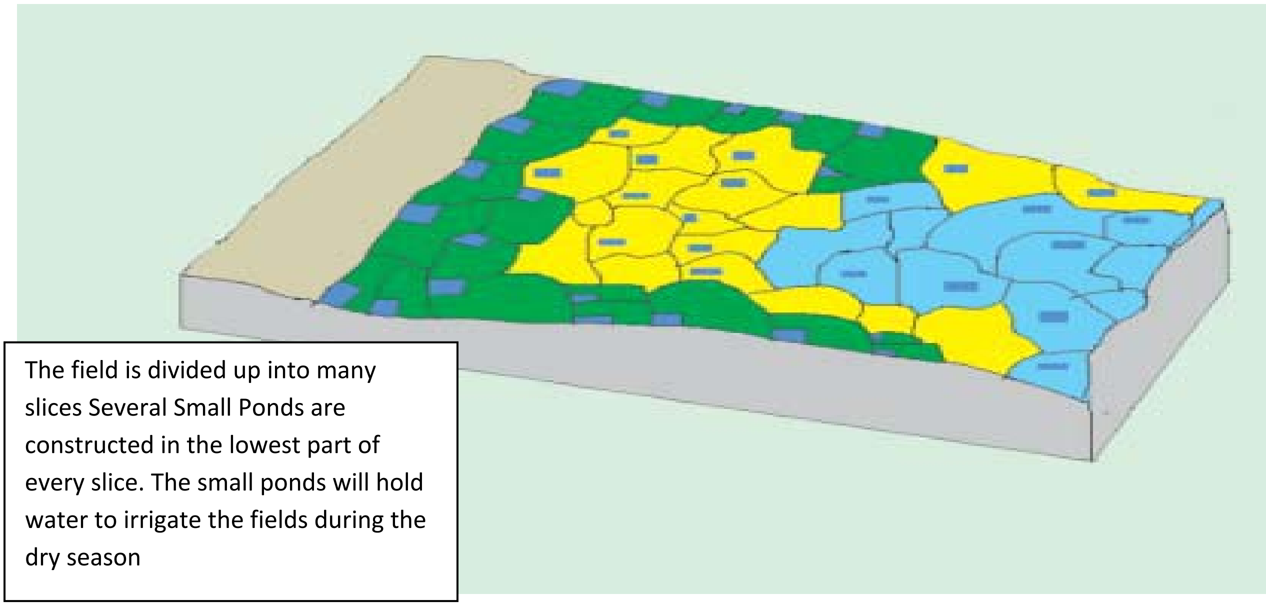
Gully Plug

A gully plug is a wall that is built in the gully. The wall can be made out of different material. It is best to use local materials. It may be useful to hire a stone mason, someone who is an expert at making walls. The walls should be built along the gully.

i. The gully is where the water naturally collects to run down hill

5% Model

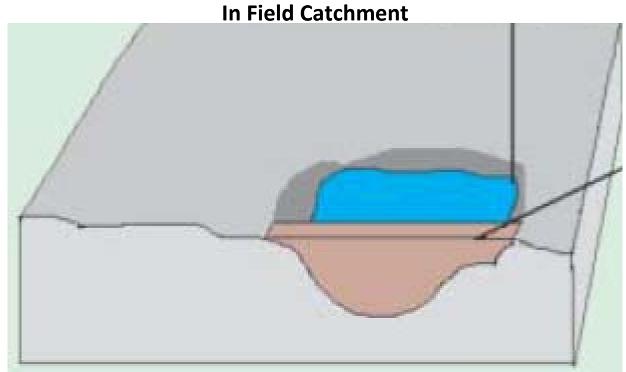
In this model, many smallponds are constructed all over the farm. The field is divided into portions. 5% of every portion is made into a pond. It is best to put the pond in the lowest part of the portion. This method is very useful for large fields that are not close to a water source.



In-Field Catchment

For this method of rainwater harvest, a small pond is dug in a small stream. The stream is used to fill the small pond, or catchment with water. This pond needs to be big enough to supply water to the crops for the entire dry season. If the water is seeping out of the pond it may be necessary to place a liner at the bottom of the pond. It is best to make a small deep pond. It is better to use this pond to irrigate perennial crops.

In Field Catchment



3. What about plants?

Plants are a very important part to maintain the health of the soil. A healthy plant will make the soil stronger. Healthy soil will also make the soil stronger. The best way to judge the health of a plant is to look at the roots. Healthy plants will have many small roots. These small roots gather water and nutrients for the plant. Using too much Nitrogen (Urea) will make the plant grow more above ground. Nitrogen can give the appearance that the plant is healthy, but really there are very few roots.

Planting instructions

The instructions will be the same if the plant is going into the earth or into a container. First remove the plant from its original container. Shake the soil from the roots. Prepare a hole by making the soil very loose. Place the tree into the ground or container so that the top root is at the ground surface. Make the new soil very wet so that the plant is happy. When the soil is properly wet, it will surround the roots of the plant.

4. And the soil?

Structure

Soil structure forms over many years. Soil structure is important because it allows space for water, nutrients, and life. In nature soil will have structure. The structure of soil can be broken. This can happen with the use of heavy equipment. It can also happen if you take natural soil and put it in a new container. When the soil loses its structure it will not be a good place for the plant.

Texture

Soil texture describes the size of the soil particle. Clay is the smallest and feels smooth. Loam is in the middle. Sand is the largest soil texture size and it will be very gritty. When the particle size is bigger, there is more oxygen in the soil. When there is more oxygen in the soil, there is more space for water and nutrients to move. A plant in sandy soil will need more water and nutrients than a plant in clay soil. Clay soil is not good for nursery production.

Organic material can also be in soil. Organic matter is not one of the texture classes. Organic material is things like compost, animal manure, or ash. It is usually a dark color. Chemicals in organic material hold water like a sponge. The organic material will hold water until the plant needs it. The organic material will also hold nutrients until the plant needs it. Organic material is very important to the health of the farm. A farm with high organic material will be a very rich farm.

Color

It is possible to understand many things from the color of the soil. Red soil means there is Iron. Blue to grey soil means there is a problem with oxygen. Black to grey soils mean there is high organic material.

White soil means there is a lot of salt (in this type of soil fertilizer will not be effective). The best agricultural soils have a very special smell, feel and color.

Life

Life is very important in the soil. Some types of life are earthworms. Other types of life may be too small to see. In the soil there is good life and bad life. To determine if there is bad life in the soil, plant one pea seed. It is important to make sure this seed does not have medicine on it. If the seed survives, then the soil is good. If the seed does not survive the soil is not good. Earthworms are a sign of good soil. If there are earthworms, but the pea seed dies, then it is possible to plant big plants, but not seeds.

5. Types of Farms

The type of farm is determined by the hills. Depending on the slope of the hill, certain rain water harvesting practices should be followed.

Steep Slope

In this type of farm, the hills are very difficult. The water will move very fast. It is very important to make sure there is a lot of organic material. It will be difficult to keep the organic material. The best way to do agriculture in this type of farm is with tranches. If there are gullies it would be important to use gully plugs.

Medium Slope

In this type of farm fast water is still a problem. It is important to plant trees and try to promote perennial agriculture. Trenches are gully plugs are important where the water is too fast. The area is also good for in-ground catchment. If there is a stream it may be good to dig a hole to save water.

Plane Land

In the plane land the water may be very close to the surface. A small hole may produce water in the dry season. This is a good type of land for tanks, ponds, and the 5% model. In this farm the water does not move as fast. If the farm is small in-ground catchment and small ponds are best. If the farm is big then the 5% model is best.