POTENTIAL APPLICATION OF VETIVER GRASS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT IN HILL TRACTS REGION OF BANGLADESH

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DEDICATED TO MY FAMILY MEMBERS
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CERTIFICATE

*This is to certify that the thesis entitle, "*POTENTIAL APPLICATION OF VETIVER GRASS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT IN HILL TRACTS REGION OF BANGLADESH*" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGROFORESTRY AND ENVIRONMENTAL SCIENCE****, embodies the result of a piece of bona fide research work carried out by* ***MAHBUBA RAHMAN*** *Registration No.* ***18-09018*** *under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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-Author

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ABSTRACT

Landslide is one of the major obstacles in the hill tract region in many parts of the world, especially in developing nations like Bangladesh. The cost of protecting landslide is high, and the national budget for such works is never sufficient. For this reason, we need to find out the best natural solutions for this problem. We think vetiver grass has the ability to protect landslide. The study aims to identify vetiver grass management and sustainable use of it to protect against natural disasters in the hill tract region. The research field data were collected at six different areas of the hill tracts region under Chattogram and Cox's Bazar district. Data were collected from 140 randomly selected people using structured questionnaires. The study results come out that vetiver grass is a very easy to establish, inexpensive, low maintenance, and incredibly efficient means of natural disaster reduction.

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ABBREVIATIONS

Full Word	Abbreviation
Vetiver Grass	VG
Social Worker	SWs
Development Agent	DAs
Government	Govt.
Height	H
Diameter of the Stem	SD
Leaf Dry Mass	LDM
Stem Dry Mass	SDM
Shoot Dry Mass	SHDM
Principle Root Dry Mass	PRDM
Secondary Root Dry Mass	SRDM
Total Root Dry Mass	TRDM
Total Dry Mass	TDM
Shoot Height Diameter Root	SHDR
Shoot Root Ratio	SRR
Quality Index of Dickson	DQI
Vetiver Grass Technology	VGT
Chattogram City Corporation	CCC
Ethio-Wetland Natural Resource	EWNR

CHAPTER 1
INTRODUCTION

Landslide is one of the most significant natural damaging disasters in hilly environments. It is a term generally used to describe the downward movement of soil, rock, and organic materials under the effects of gravity and also the landform that results from such movement (Highland and Bobrowsky, 2008). Physiographically, most of the areas of Bangladesh is a floodplain and only 18% is hilly and tract area where a considerable proportion of people are living due to growing urbanization (Islam and Uddin, 2002). Landslide is becoming a regular hazard in the urbanized hilly areas in the Chattogram division. This division has already been recognized as one of the most vulnerable divisions to a landslide. Chattogram hills are degrading by different anthropogenic stresses such as hill cutting for construction, sand and clay mining, the establishment of a settlement in foothills, deforestation, etc. Along with these, there are several other reasons responsible for creating vulnerability to the landslide. Also, the landslide is a critical problem affecting the economic welfare, food security, and public health of communities. There are lots of expensive methods for controlling landslide which can't be achievable in developing countries like Bangladesh. Because from a strictly economic point of view, the cost of remediating these problems is high, and the state budget for such works is never sufficient.

Considering all these problems the administration has found an unconventional, innovative, and low-cost way to prevent landslide by using vetiver grass, locally known as "Binna Grass" in Bangladesh. Vetiver (*Chrysopogon zizanioides*, formerly known as *Vetiveria zizanioides*) is a perennial grass belonging to the Poaceae family that is native to India. It can grow on both silt and clay soil. The grass can survive extreme weather conditions ranging from 14 degrees Celsius to 55 degrees Celsius. Vetiver grass has been used in many tropical countries and has been shown to be a simple and economical method to conserve soil by slowing the velocity of water and trapping sediment, filtering out nutrients, and stabilizing steep slopes (Ruksakulpiwat *et al.*, 2007). Vetiver has great potential for reducing runoff and soil loss, in which the vetiver

strips significantly hold back soil from the field (Donjadee *et al.,* 2010). It has a deep thick root system which spreads vertically rather than horizontally, which allows it to efficiently endure harsh conditions (Maneecharoen *et al.*, 2013). It plays a vital role in Bangladesh agricultural land management mainly to fix boundaries between paddy fields and leaves are used for thatching. Other uses are control landslide, reducing soil erosion, practicing of slope protection the technique in Rohingya settlement area and it acceptable and eco-friendly tools for social development in the hill tract region.

Chattogram City Corporation (CCC) has taken a project to plant vetiver grass on hills in the city aiming to prevent the hill-slide that claims life frequently. The project also aims at addressing the long-drawn waterlogging crisis in the port city through developing a drainage system. The project will be implemented with the fund from the 'Bangladesh Climate Change Trust Fund' under the Environment and Forest ministry (Source: Daily Sun). The trials of vetiver grass on 28 km of embankment project built on the Kangsha River in the Netrokona District under the Dampara Water Management Project (DWMP) in 2000. DWMP demonstration sites proved that the vetiver grass provides outstanding protection against erosion while also being a sustainable supply of fodder and thatch Thomas et al. (2002). The use of vetiver in controlling water-borne erosion with particular reference to Bangladesh coastal region through Coastal Embankment Rehabilitation Project (CERP), Islam (2003). Coastal Embankment Rehabilitation Project (CERP) aimed at developing cost-effective systems of erosion control to save lives and properties of the coastal areas. This project has made a breakthrough in the last five years in disseminating the importance of Vetiver Grass Technology (VGT) to government officials, NGO workers, and grass-root level community as well as by introducing about half a million tillers in the field. Through continuous efforts of information dissemination, training, small scale field implementation, and motivation, the important role of vetiver grass technology (VGT) has been well recognized by the implementing agency (Bangladesh Water Development Board), NGOs, and about one thousand families involved in field implementation and the larger community nearby.

VGT is now a well-discussed issue as an effective system of erosion control among professionals from multi-disciplines. The introducing stage has been covered successfully but there is still a long way to proceed for the vetiver system to be adopted by government agencies in our country.

Vetiver grass can play a very important role in slope protection and poverty alleviation in Bangladesh. For these aspects interest in vetiver grass technology in Bangladesh increased significantly in recent times. Some studies have been conducted in this area; there is no integrated approach to study on vetiver. We think that a systematic scientific study is necessary for developing the vetiver system for boosting the confidence of the policymakers and institutional research which will involve the faculties (who are involved in the decision making of different projects of Bangladesh) and students (future leaders) with the collaboration of implementing agencies (both government and NGO) are required for the sustainable development of the technology. This study results come out peoples' perception of the use of vetiver grass and to recognize the major role it played in soil erosion, slope stabilization, soil & water conservation, fodder. Also, vetiver grass very easy to establish, increase income, inexpensive, low maintenance, and incredibly efficient means of natural disaster reduction. The majority of the peoples said awareness, sustainable policy, government, NGO support, and technical support are important key tactics for the successful adoption of vetiver grass in the hill tract region for overall social development.

Objectives:

1. To assess the potential application of vetiver plantation in hill tracts region
2. To identify the practices followed for mudslide and soil erosion control for environmental management
3. To evaluate people's perception on adoption of vetiver plantation in hill tracts region
4. To justify the social development in hill tracts region by vetiver plantation
5. To examine the growth character of vetiver grass for environmental management strategy

CHAPTER 2
REVIEW OF LITERATURE

2.1 Vetiver grass (*vetiveria zizanioides*) and vetiver plantation

Alam *et al.,* (2005) found that Vetiver (*Vetiveria zizanioides*) grass is perennial in nature and tall grows wild in semiarid and arid with climatically versatile situations. Agronomically it has spongy, branched root system with fine rootlets, oil being extracted for perfume. The dry aromatic roots are used to make curtains, mats, fans and other fancy goods as the product emits a sweet cooling aroma for a long period when moistened during summer season.

Hengchaovanich and Nilaweera (1996) highlighted that in general, for slope stabilization, vetiver is planted in rows on the contour so that soils build up behind the hedge and water run-off is trapped and allowed to filter either into the soil or through each succeeding hedge on its down-slope progression. VGT is therefore quite different to the classical approach to soil conservation where earth bunds are created mechanically that channel run-off into waterways. This bounding methodology is expensive, breaks down over time and results in much land being removed from production. Hedgerow spacing varies between 1- and 2-meters vertical interval, depending upon slope gradient, soil type, slope length and climatic circumstances.

West *et al.,* (1996) pointed that the trimming of leaf growth to about 40 cm in height stimulates root growth and is desirable particularly in the first two years of growth. Thereafter, the practice should be followed if possible but if labour constraints do not permit will not result in retarded growth. Valuable by-products of trimming are: mulch, bedding, and livestock fodder.

Vetiver, a graminae, is extremely sensitive to Roundup weedicide (*glyphosphate*) to which it should not be exposed. However, other herbicides, pre-emergent or post emergent chemicals, such as Atrazine or 2, 4D based, can be used for broad leaf weed control.

2.2 Nature of growth characteristics of vetiver grass (*vetiveria zizanioides*)

Truong and Baker (1998) some Morphological Characteristics of vetiver grass are stated below:

i. Vetiver grass does not have solons or rhizomes. Its massive finely structured root system can grow very fast; in some applications rooting depth can reach 3-4m in the first year. This deep root system makes Vetiver plant extremely drought tolerant and difficult to dislodge by strong water currents.
ii. Stiff and erect stems that can stand up to relatively deep-water flows
iii. Highly resistance to pests, diseases and fire.
iv. A dense hedge is formed when planted close together, acting as a very effective sediment filter and water spreader.
v. New shoots develop from the underground crown making Vetiver resistant to fire, frosts, traffic and heavy grazing pressure.
vi. When buried by trapped sediment new roots grow from nodes. Vetiver will continue to grow up with the deposited.

Truong and Baker (1998) also reported some Physiological Characteristics of Vetiver grass. These are -

i. Tolerance to extreme climatic variations such as prolonged drought, flood, submergence and temperature levels ranging from -20 ºC to 55 ºC.
ii. Vetiver has been found to thrive under rainfall ranging from 300 mm to 6000 mm per annum.
iii. Ability to regrow rapidly after being affected by drought, frost, fire, saline and other adverse conditions when the adverse effects are removed.
iv. Adaptability to a wide range of soil types (pH 3.0 to 10.5) (Truong and Baker 1998).
v. Highly tolerant to growing media that are high in acidity, alkalinity, salinity, sodality and magnesium.
vi. Highly tolerant to Al, Mn, As, Cd, Cr, Ni, Pb, Hg, Se and Zn in the soil

Truong *et al.,* (2003) found that the vetiver plant is mostly recommended in tropical and subtropical areas. The special attributes of vetiver are that it can grow on sites where annual rainfall ranges from 200 to 5,000 mm. It can survive in temperature ranging from 0 °C to 50 °C. It grows on highly acidic soil types (pH ranges from 3.0 to 10.5). It is also high tolerant to Al, Mn, As, Cd, Cr, Ni, Pb, Hg, Se and Zn in the soil.

Islam *et al.,* (2003) highlighted that mean annual rainfall varies from 1500 mm in the southern part of our country (Chattogram district) to over 3750 mm and in the southeast (Cox's Bazar) is about 2506 mm in Patuakhali district. The heaviest rainfall occurs in July and ranges from 350~875 mm. The soil salinity varies from 2.0~10.0 dSm-1 for most of the area which is very favourable for growing vetiver grass. There our study area is also existing. Therefore, it is clear that the local climatic and soil condition is suitable for vetiver grass to grow at the coast of Bangladesh.

Smeal *et al.,* (2003) urged that Vetiver hedges can survive even for more than 100 years. Even in the soil with ECse values 7.8 dSm-1, the relative yield of vetiver grass is found to be 100%. Its roots are very strong with high tensile strength of 75 MPa.

2.3 Vetiver grass (*vetiveria zizanioides*) origin and its distribution

Truong *et al.,* (2000) Binna or Vetiver grass (*Vetiveria zizanioides*) is a perennial grass belonging to the family of Poaceae which is used in more than 100 countries of the world for different erosion protection works. It is an ancient grass with its centre of origin in south India. Other related species such as *vetiveria nigritana* and *vetiveria nemoralis* have origins in Africa and Southeast Asia, respectively. These species do not have all the characteristics of *vetiveria zizanioides* and are not recommended as a base component of vetiver grass technology.

Recently the International Maritime Organization (IMO) mentioned that over two million Vetiver grass plants were distributed among Rohingya as to reduce soil erosion and the risk of landslides in the makeshift camps where thousands of people are at risk from impending monsoon rains. UN Migration Agency IOM has distributed the grass plants among the displaced people in a bid to reduce soil erosion as well as risk of landslides in Rohingya camps.

2.4 Availability of vetiver grass (*vetiveria zizanioides*) in Bangladesh

Rahman *et al.,* (1996) proposed that Bangladesh has an abundant supply of vetiver grass. It is commonly found in almost all the districts. While mapping available places of vetiver grass in Bangladesh, they found that vetiver grass is available in 85% of the total land. Naturally grown vetiver grass found in Kuakata, Pubail, Haor and hill track regions in a very large portion. It was also claimed that Soil of Kuakata and Haor area is salty sand (SM) while the soil of Pubail is silty clay (CL) which means that vetiver can grow in both types of soils. Countrywide study is yet to be done to have a clear profile of availability and uses of vetiver.

2.5 Vetiver grass (*vetiveria zizanioides*) invasiveness

According to U.S. National Academy of Sciences (1993) it is critical that any plant used for environmental protection is not invasive and will not become a weed. The South Indian form of vetiver is not considered a weed in the dozens of places where it has been planted.

Truong and Creighton (1994) investigated that most of the cultivars of *Vetiveria zizanioides* that are now distributed globally have closely similar DNA characteristics and only a few have been shown to produce viable seeds or to become invasive.

In Queensland a sterile cultivar was selected and rigorously monitored and tested over an eight-year period commencing in 1989. This cultivar produced no caryopses when grown under glasshouse and field conditions and in dry land, irrigated and wetland habitats. It is registered as Monto Vetiver in Queensland.

2.6 Extremity (fire and temperature) of vetiver grass (*vetiveria zizanioides*) adaptation

Truong *et al.,* (1999) Vetiver grass grows up to 2 m high with a strong, dense and vertical root system measuring <3 m, hydrophyte, thrives under xerophytes conditions Best adoptability is with temperature mean m 18-25 °C, mean coldest month 5 °C, absolute minimum 15 °C and plants die when ground frozen.

Summer Temperature should < 25 ºC is required for good growth. Rain fall is low as 300 mm, but above 700 mm preferable will survive total drought, but normally requires a wet season of at least three months. Ideal is well spread monthly rainfall. Humidity: Grows better under humid conditions, but also does well under low humidity. Sunshine: Difficult to establish under shade, when shade is removed growth recovery is rapid. Soil: Grows best on deep sandy soils, however, it will grow on most soil types ranging from black cracking vertosols through to red alditols. Grows on rubble, both acid (pH 3.3) and alkali (pH 9.5), Grows on both shallow and deep soils Up to about 2,000 m. above 2000 m altitude vetiver growth may be constrained by low temperatures.

Paul Truong *et al.,* (2000-2008) recent research showed that although vetiver is a tropical grass, it can survive and thrive under extremely cold conditions. Under frosty weather its top growth dies back or becomes dormant and purple ‘in colour under frost conditions but its underground growing points survived. In Australia, vetiver growth was not affected by severe frost at –14 ºC and it survived for a short period at –22 ºC (-8 ºF) in northern China. In Georgia (USA), vetiver survived in soil temperature of -10 ºC, but not at –15 ºC. 25 ºC was optimal soil temperature for root growth, but vetiver roots continued to grow at 13ºC. Although very little shoot growth occurred at the soil temperature range of 15 ºC (day) and 13 ºC root growth continued at the rate of 12.6 cm/day, indicating that vetiver grass was not dormant at this temperature and extrapolation suggested that root dormancy occurred at about 5 ºC.

Truong *et al.,* (2000) indicated that with adequate N and P supply, vetiver growth was not affected even under extremely acidic conditions (pH = 3.0) and at a soil Aluminium Saturation Percent s between 83-87%, which is extremely high as growth of most plants is affected at Al Saturation Percent s less than 30%. In addition, vetiver growth was not affected when extractable manganese in the soil reached 578 mg/Kg and plant manganese content was as high as 890 mg/Kg.

Rodriguez *et al.,* (1993) proposed With a salinity threshold level at ECse = 8 dS/m, vetiver grass compares favourably with some of the most salt tolerant crop and pasture species grown in Australia such as Bermuda Grass (*Cynodon dactylon*) with a threshold at 6.9 dSm-1; Rhodes Grass (*Chloris guyana*) at 7.0 dS/m; Wheat Grass (*Thynopyron elongatum*) at 7.5 dS/m and barley (*Hordeum vulgare*) at 7.7 dS/m. Vetiver grew satisfactorily on a sodium betonies tailings with Exchangeable Sodium Percent (ESP) of 48% and a coalmine overburden with an ESP of 33%.

Dalton *et al.,* (1996) found that Vetiver is highly tolerant to As, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn. The distribution of heavy metals in vetiver plant can be divided into three groups:

i. Very little of the As, Cd, Cr and Hg absorbed was translocated to the shoots (1% to 5%)
ii. A moderate proportion of Cu, Pb, Ni and Se were translocated (16% to 33%) to the top and Zn was almost evenly distributed between shoot and root (40%).

2.7 Vetiver System

Nikhil *et al.,* (1998) highlighted that the Vetiver Grass System (VGS) is a system of soil and water conservation whose main component is the use of the vetiver plant in hedgerows, infrastructure stabilization, pollution control, waste water treatment, mitigation, and rehabilitation, sediment control, prevention of storm damage, and many other environmental protection applications through bioengineering and phytoremediation process.

Truong and Hart (2001) Indian research stations (G. Bharad) were the first to undertake serious soil conservation related work from 1987, closely followed by Malaysia's Rubber Research Institute (P.K/Yoon) and Thailand's Royal Project's Development Board at the insistence of the King of Thailand. By this time research was moving into new areas including vetiver's use from highway stabilization, water quality improvement, disaster mitigation, mine land rehabilitation and handicrafts.

Paul Truong *et al.,* (1990) Australia researched aspects relating to flood mitigation, heavy (toxic) metal tolerance, water quality improvement and constructed wetlands. Chinese researchers headed by Xia Hanping followed up on Truong's work and carried out extensive research on the use of vetiver for water quality improvement and at the same time undertook large scale applications of VGT to highway, railroad and landfill stabilization.

Currently a new and large vetiver program is developing in Vietnam for a wide range of applications focusing on disaster mitigation and backed by research and data collection. India, Malaysia, Thailand, Australia, China and Vietnam have been or are currently important centres of research and development. Even so there are other initiatives taking place that are important in other parts of the world. Today over 100 tropical and subtropical countries around the world are fairly serious users of vetiver. In addition, special niche environments such as California and some Mediterranean countries are developing techniques to use Vetiver Systems to mitigate problems that impact their infrastructure. Some of this is backed by local research, but much of the VS development is undertaken on the basis of research done elsewhere, and the use of vetiver grass cultivars that are related to those non-invasive types from south India. Such cultivars include: Karnataka, Sunshine, Hoffman, and Monto. Combine the two and one can expect good results if applied correctly.

Bharad *et al.,* (1987) closely followed by Malaysia's Rubber Research Institute (P.K/Yoon) and Thailand's Royal Project's Development Board at the insistence of the King of Thailand. By this time research was moving into new areas including vetiver's use from highway stabilization, water quality improvement, disaster mitigation, mine land rehabilitation and handicrafts.

2.8 Manifold use of vetiver grass (*vetiveria zizanioides*)

2.8.1 Crop protection and pest repellent

Lal *et al.,* (1981) Vetiver can be used for crop protection of. physical and biological measures of erosion control such as contouring, tillage, soil mulching, terracing, alley-cropping, agroforestry, crop rotation, bunding and tied-ridging have been used to varying degrees and successes in Nigeria, depending on localities the essential oil of vetiver has anti-fungal properties against *Rhizoctonia solani* Kuhn. As mulch, vetiver is used for weed control in coffee, cocoa and tea plantations. It builds a barrier in the form of a thick mat. When the mulch breaks down, soil organic matter is built up and additional nutrients for crops.

2.8.2 Medicinal use of vetiver grass

John *et al.,* (2003) reported that Vetiver has been used in traditional medicine in South Asia (India, Pakistan, Sri Lanka), Southeast Asia (Malaysia, Indonesia, Thailand), and West Africa. Old Tamil literature mentions the use of vetiver for medical purposes. The health benefits of Vetiver Essential Oil can be attributed to its properties like anti-inflammatory, anti-septic, aphrodisiac, cicatrising, nervine, sedative, tonic and vulnerary. The very soothing and cooling effect of this essential oil calms and pacifies all sorts of inflammations. But it is particularly good in giving relief from inflammations in circulatory system and nervous system. It is found to be an appropriate treatment for inflammations caused by sun stroke, dehydration and loo (name given to very hot and dry winds prevalent during summers in the dry regions of India and few neighbouring countries).

2.8.3 Vetiver grass as fungicides and acaricides

In New Zealand, some scientist noticed that fungal attacks on the vetiver mulched plants have virtually disappeared and there seem to be little, if any other pest action around the host plants.

In Thailand, it was found that 10% vetiver oils of different ecotypes were variably able to control cow ticks at both the larval and adult stages. Furthermore, extract of dry root was able to control adult stage of ticks better than larval stage.

2.8.4 Vetiver grass as animal feed

Anon *et al.,* (1990) reported that the young vetiver leaves can be ground to feed fish and livestock, but mature leaves cannot be used for such purposes because their nutritive value is lower than other grasses, and because of the high roughness and silica content. The analysis also indicated that vetiver has the content of crude protein lower than that of other grasses used for animal feed.

Panichpol *et al.,* (1996) In the State of Karnataka, India, vetiver is planted along the field boundaries and cut every two weeks or less for use as fodder. Vetiver was found to have relatively higher structural carbohydrates as compared to native grass and rice straw. On the other hand, it also had optimal levels of crude protein, considered to be enough to maximize intake and digestion of the vetiver forage. It was concluded that vetiver may be used as ruminant feed if it is mixed with other good quality feed and forages.

2.8.5 Miscellaneous of vetiver grass

Truong *et al.,* (2013) highlighted that Vetiver grass is used as roof thatch (it lasts longer than other materials), mud brick-making for housing construction, strings and ropes and ornamentals (for the light purple flowers). Garlands made of vetiver grass are used to adorn the murti of Lord Nataraja (Shiva) in Hindu temples. It is also a favourite offering to Ganesha. Vetiver oil has been used in an effort to track where mosquitoes live during dry seasons in Sub-Saharan Africa. Mosquitoes were tagged with strings soaked then released. Due to its fibrous properties, the plant can also be used for handicrafts, ropes and more.

2.9 Use of vetiver grass (*vetiveria zizanioides*) in agriculture system

Greenfield *et al.,* (2002) stated that Vetiver grass has been used first by Indian farmers for soil and water conservation more than 200 years ago, its real impact on land stabilization/reclamation, soil erosion and sediment control only started in the late 1980's

following its promotion by the World Bank While it still plays vital role in agriculture, the unique morphological, physiological and ecological characteristics of the grass including its tolerance to highly adverse growing conditions and tolerance to high levels of toxicities provide an unique bio-engineering tool for other, non-agricultural applications such as land stabilization/reclamation, soil erosion and sediment control.

Maistrello *et al.,* (2001) found Termites are an example of serious plants menaces threatening agriculture producers and leading to huge losses of perennial crops. Biological methods have been proposed for termite control as an alternative to the use of chemicals that lead to additional pollution and development of resistance by the target insects. Within the bio-based methods, the use of plant essential oils with insecticidal action has become popular. Vetiver grass oil, proved to be one of the most effective due to its long-lasting activity. Various authors have proved the effectiveness of the oil present in vetiver's roots for termite control.

Nix *et al.,* (2006) evaluated the effect of using vetiver grass roots as soil mulch to act against the same subterranean termites C. formosanus. In this study, vetiver root mulch (with a root to sand ratio of 25% in mass) proved to reduce termite tunnelling activities/wood consumption and increased termite mortality.

Van *et al.,* (2015) proved that vetiver grass compost enhances cacao (Theobroma cacao) plant growth and contributes for termite control around such crop. Besides the proven technical efficiency for termite control in various crops.

Ewetola *et al.,* (2017) investigated social acceptance and Nigerian farmer's perception on vetiver grass application for termite control. The authors identified the necessity for the increase of the farmer's awareness regarding vetiver grass potential for control of termites.

2.10 Current status of vetiver grass (*vetiveria zizanioides*) plantation in hill tract region

Islam *et al.,* (2005) found that shrub species of local named Durba (*Cynodon dectylon*), Chalia, Aralie, Jhora, Dolghas (*Hydrilla verticillata*), Shonghas, Binna (*Vetiveria zizanioides*), Chesr, Tihera, Agali, Bannalata (*Mikania cordata*), Bazra, Gini, Tara,

Cowpee and Ipil-ipil (*Leucaena leucochephala*) etc. are found in the study area. However local people are practicing this method without following the correct grass planting technique. Hence, vetiver is considered in this research as potential vegetation in protecting the coastal embankments against cyclonic tidal surge. Bangladesh is an advantageous position as it has an abundant supply of vetiver grass. Field survey was carried out to find out the grass available in the coast, which are helpful for erosion control as well as a labour-intensive technique.

2.11 Vetiver grass (*vetiveria zizanioides*) for roadside and slope protection

Truong *et al.,* (2003) presently vetiver grass has been widely used for erosion and sediment control on steep slopes around the world: including Africa, Asia, central and south America, southern Europe and Australia where it has been used successfully to stabilise steep batters of road and railway in north, central and south east Queensland. In China, VS has been used for erosion and sediment control on more than 150000 km of railway, highway and road batters in the last 5 years.

Intaphan *et al.,* (1997) stated that the use of vegetation for erosion control and slope stabilization have been used for centuries. Its popularity has increased in the last two decades. Even over coal mining overburden dumps slopes plantations of vetiver grass not only add biomass but also preserve top spreader soil from erosion.

The use of vegetation as a bio-engineering tool for erosion control and slope stabilization and due to the low costs of bio-engineering techniques and vegetative approach, land disturbance by construction activities has resulted in soil erosion increases from two to forty thousand times the pre-construction rates with sediment being the principal transport mechanism for a range of pollutants entering water courses. Its real impact on land stabilization, soil erosion and sediment control only started in the late 1980‘s following its promotion by the World Bank. Besides this, vetiver can purify mine water in the mine effluent pond and can be used for agricultural purposes.

2.12 Vetiver grass (*vetiveria zizanioides*) treatments for soil and water conservation

Babola *et al.,* (2003) found that In Nigeria, vetiver strips were established on 6% slopes for three growing seasons to assess effects of vetiver grass on soil and water loss, soil

moisture retention and crop yields. Results showed that soil physical and chemical conditions were ameliorated behind the vetiver strip for a distance of 20m. Crop yields were increased by a range 11 – 26% for cowpea and by about 50% for maize under vetiver management. Soil loss and runoff water at the end of 20m runoff plots were 70% and 130% higher respectively in non-vetiver plots than vetiver plots. Vetiver strips increased soil moisture storage by a range of 1.9% to 50.1% at various soil depths. Eroded soils on non-vetiver plots were consistently richer in nutrient contents than on vetiver plots. Nitrogen use efficiency was enhanced by about 40%. This work demonstrates the usefulness of vetiver grass as a soil and water conservation measure in the Nigerian environment.

Truong *et al.,* (1993) stated that in India on cropping land with 1.7% slope, Vetiver contour hedges reduced runoff (as percent of rainfall) from 23.3% (control) to 15.5%, soil loss from 14.4 t/ha to 3.9 t/ha and sorghum yield increased from 2.52 t/ha to 2.88 t/ha over a four-year period. The yield increase was attributed to mainly in situ soil and water conservation over the entire top sequence under the Vetiver hedge system.

Rao *et al.,* (1992) urged that under small plot conditions at the International Crops Research Institute for the Semi-Arid Tropics vetiver hedges gave more effective runoff and soil loss control than lemon grass or stone bunds.

Runoff from the vetiver plots was only 44% of that of the control plots on 2.8% slope and 16% on 0.6% slope. Relative to control plots, average reductions of 69% in runoff and 76% in soil loss were recorded from vetiver plots.

Grimshaw *et al.,* (1993) Similar results were also reported on a range of soil types, land slopes and crops in Venezuela and Indonesia In Natal, South Africa, vetiver hedges have increasingly replaced contour banks and waterways on steep cane lands, where farmers have found that the Vetiver system is the most effective and low-cost form of soil and water conservation in the long term.

Zheng *et al.,* (1997) indicated that V. *zizanioides* is not a hydrophyte but it prefers wet and waterlogged habitat where it can grow and develop even though a large portion of its shoots are submerged for relatively long period, normally in water. Many scientists have

confirmed that vetiver grass is powerful to remove nitrogen and phosphorus from water and, therefore, is a good plant for purifying eutrophic water.

Troung *et al.,* (2003) found that vetiver grass (*Vetiveria zizanioides*), a perennial grass, is fast growing grass with a deep root system and high biomass production. Due to its unique morphological characteristics and its tolerance of adverse environmental conditions, it has been used effectively for wastewater treatment.

2.13 Vetiver grass (*vetiveria zizanioides*) for landslide/mudslide protection

Babola *et al.,* (2003) indicated that several aspects of vetiver make it an excellent erosion control plant in warmer climates. Rows of plants oriented perpendicularly to the slope direction has used as semi permeable barriers that reduce the surface runoff, amount of infiltrated water increases and the runoff and soil loss amounts decrease. This makes vetiver an excellent stabilizing hedge for stream banks, terraces, and rice paddies and protects soil from sheet erosion. The roots bind to the soil; therefore, it can't dislodge. Vetiver has also been used to stabilize railway cuttings/embankments in geologically challenging situations in an attempt to prevent mudslides and rock falls, the Konkani railway in Western India being an example. The plant also penetrates and loosens compacted soils.

2.14 Cultivation, establishment and management of vetiver grass (*vetiveria zizanioides*)

Truong *et al.,* (2002) highlighted that usually, little management is needed once the hedge is established. However, cutting the tops of the plants produces more tailoring and therefore a denser hedge. It can grow on both acidic (pH 3.0) and alkaline (pH 11.0) soils, and is tolerant to high levels of various trace metals such as arsenic, cadmium, copper, chromium and nickel. It produces up to 2 m high plant with a strong dense and mainly vertical root system often measuring three meters, useful in soil erosion control.

NRC (1993) reported that Vetiver grass is difficult to kill by fire, grazing, drought, or other natural force. However, if necessary, it can be eliminated by slicing off the crown. Because the crown is close to the surface, it can be cut off fairly easily with a shovel or

tractor blade. Although the plant is resistant to most herbicides, it succumbs to those based on glyphosate.

Hengchaovanich and Nilaweera (1996) also insisted that it is critical to the effectiveness of the technology to establish a solid vegetative barrier without gaps and, if they do occur, to fill these in as rapidly as possible. On steeper slopes, typically those occurring in engineered structures such as dams, roads, railways etc. the standard spacing between plants should be not more than 10 cm. The width of a clenched fist is a good guide. For less severe slopes, often on agricultural land, spacing of 15 cm can be effective.

2.15 Local adoption strategy of vetiver grass (*vetiveria zizanioides*)

Brown *et al.,* (1981) indicated that adoption of any innovation results from a learning or communication process. Thus, in examining the process of diffusion of vetiver technology, it is important to identify factors relating to the effective flow of information, the characteristics of information flows, information reception and resistance to adoption.

Olaniran *et al.,* (2014) highlighted that adoption, knowledge and management of insect pests of fruit vegetables in the same study area, chemical control as one of the strategies used for the control of the insect pests. Several authors had reported the effectiveness of synthetic termiticides in termite control.

2.16 Social improvements through vetiver grass (*vetiveria zizanioides*) plantation

Habtamu *et al.,* (2009) Income and livelihood diversification is one of the several strategies available to enhance social resilience in the face of climate change. On top of its ecological services, vetiver is used as fodder and fibre and generates income for local communities. Its leaves and roots can be used for other purposes (especially its leaves), which usually have to be cut to keep the vetiver rows in order and can be used for roofing as well as making handicraft products to earn extra income.

Seru, the Officer in Charge of Land Use and Soil Conservation of the Fijian Department of Primary Industries made the following summary (2001): "There is no doubt in my mind that Vetiver grass provides a very effective means of soil erosion control on steep lands. It is not a weed, it is very simple and practical for farmers to use, it does not

compete with crops but it is a living barrier and it needs proper maintenance to provide the maximum benefit".

East Bali Poverty Project (1998) first identified Vetiver grass as the best option to pilot land stabilization on the steep and sandy mountain slopes for trials of improved agriculture. Also, EBPP team to integrate creative handicrafts into the children's school arts curriculum. Learning about the aromatic roots, many chose to produce simple fans, whilst others experimented with making drinks coasters, dolls, animals and simple balls. Dried grass was used to make simple dolls and hand-brooms.

2.17 Environmental and disaster risk management through vetiver grass (*vetiveria zizanioides*) plantation

Thomas *et al.,* (2002) presented the trials of vetiver grass on 28 km of embankment project built on the Kangsha River in Netrokona District under Dampara Water Management Project (DWMP) in 2000. DWMP demonstration sites proved that the vetiver grass provides outstanding protection against erosion while also being a sustainable supply of fodder and thatch.

Islam *et al.,* (2003) found that the use of vetiver in controlling water borne erosion with particular reference to Bangladesh coastal region through Coastal Embankment Rehabilitation Project (CERP).

Vetiver was introduced in 18 coastal polders and 87 km of earthen embankments where half a million vetiver tillers were planted from 1999 to 2003. Vetiver was also planted in different types of low-cost toe-protection trials. Success was achieved where initial protection and watering could be ensured. Human and animal interferences, seasonal variations in soil moisture content, sea water level variation, salinity, threat of washing away by cyclones or tidal surges were found as limiting factors.

Grimshaw *et al.,* (2006) stated that many countries are effectively using naturally grown vetiver grass (*Vetiveria zizanioides*) to protect embankment slopes and river banks for its special attributes. Vetiver grass is an ancient grass with its centre of origin in south India. Other related species such as V. *nigritanaand* V. *nemoralishave* origins in Africa and Southeast Asia, respectively. These species do not have all the characteristics of V.

zizanioidesand are not recommended as a base component of vetiver grass technology. These initial studies recommended field trials for investigating the efficacy in slope protection and erosion control.

2.18 Prospect and limitations of vetiver grass (*vetiveria zizanioides*) plantation

Edenilson *et al.,* (2017) insisted that despite their vast application potential, vetiver cultivation and use have few drawbacks that need to be addressed carefully before its implementation at large scale. At present, the main goal of vetiver cultivation in many parts of the world is to utilize the roots to extract oil. When the roots are dug from the ground, the soil becomes more vulnerable to erosion leading to negative impacts. Therefore, if the purpose is to use vetiver for conservation purposes, stringent rules are required for vetiver cultivation and roots harvesting. Control measures should be implemented by the corporate to forbid collection of roots from such misuse. Government should also charge heavy fines for such collection and form several vigilant teams to check such actions. Since these measures would not be socially acceptable due to the necessity of strong and authoritarian governance, a scientific research option should be encouraged.

Truong *et al.,* (2002) submitted that although vetiver is very tolerant to some extreme soil and climatic conditions as typical tropical grass, it is intolerant to shading. Shading will reduce its growth and in extreme cases, may even eliminate vetiver in the long term.

Therefore, vetiver grows best in an open and weed free environment, weed control may be needed during establishment phase. On erodible or unstable ground vetiver first reduces erosion, stabilizes the erodible ground (particularly steep slopes), then because of nutrient and moisture conservation, improves its micro-environment so other volunteered or sown plants can establish later. Because of these characteristics' vetiver can be considered as a nurse plant on disturbed lands.

CHAPTER 3
MATERIALS AND METHODS

3.1 General Description of the Study Area

3.1.1 Location

Chattogram is the second-largest and main seaport of Bangladesh. The city is comprised of small hills and narrow valleys, bounded by the Karnaphuli River to the south-east, the Bay of Bengal to the west, and Halda River to the north-east. The city has a population of about 5 million and is constantly growing (Community Report, Chattogram District 2012). The study area, CMA, is situated within 22° 14′ and 22° 24′ 30″ north latitude and between 91° 46′ and 91° 53′ east longitude. The total area of CMA is approximately 775 km2 (using Bangladesh Transverse Mercator projection). CMA is also known as 'Chattogram Metropolitan Master Plan (CMMP) Surveyed Area'. There are two study areas in Chattogram of this research. Those areas description given below:

Khulshi Thana (Chattogram metropolitan) area 12.09 sq km and, located between 22°20' and 22°23' north latitudes and in between 91°46' and 91°49' east longitudes. It is bounded by bayejid bostami thana and sitakunda upazila on the north, double mooring and pahartali thanas on the south, panchlaish and kotwali thanas on the east, Pahartali thana on the west. The thana consists of 3 full and 1-part city wards and 45 city mahallas. The average population of each ward and mahalla are 69656 and 6192 respectively. It is totally urban area our target location for study are Lalkhan Bazar and North Pahartali area. This area distance from capital is 258 km. (Source: Banglapedia).

Rangunia Upazila is located in between 22°18' and 22°37' north latitudes and in between 91°58' and 92°08' east longitudes. It has 46,176 households and a total area of 347.72 km². It is bounded by Chandanaish Upazila on the south; Patiya Upazila, Boalkhali Upazila, Raozan Upazila & Kawkhali Upazila of Rangamati District on the west; Kawkhali Upazila of Rangamati District on the north and Kaptai Upazila & Rajasthali Upazila of Rangamati District and Bandarban Sadar Upazila on the east. Rangunia is the administrative headquarter of this upazila. The upazila consists of 1 paurashava, 9 wards, 22 mahallas, 15 unions, 74 populated mauzas and 138 villages. The average size of population of each ward and mahalla are 3627 and 1484 respectively. On the other hand, the average size of population of each union, mauza and village are 20424, 4140 and 2220 respectively. For our study the target area is Rajanagar and Kodala. This area distance from capital is 298 km. (Source: Banglapedia)

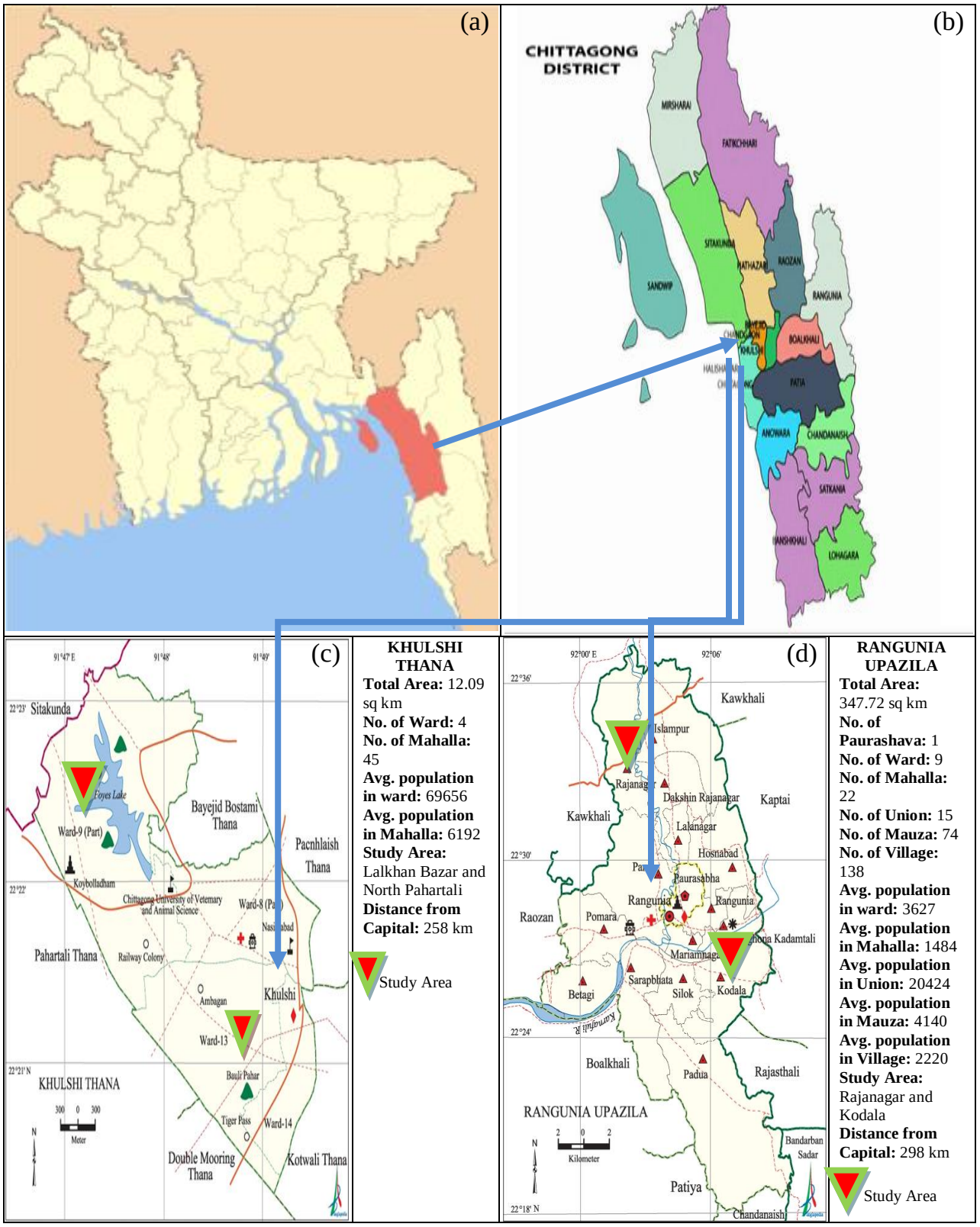

Plate 1: Step wise location of study area where (a) Bangladesh (b) Chattogram District (c) Khulshi Thana (d) Rangunia Upazila

Cox’s Bazar District that is one of the five districts of the south-eastern Chattogram Hill Tracts region. The study area, CBM, is approximately situated within 22° 23′ 30″ and 22° 27′ 30″ north latitude and between 91° 58′ and 92° 2’ east longitude. It is bounded on the west by the Bay of Bengal, on the northeast by Bakkhali River, and on the north by Moheshkhali Channel. The total area of CBM is about 20.78 sq.km. The population of CBM increased fourfold in the past two decades (1991–2011), which is now around 1, 67,477. (BBS 2013)

Ukhia Upazila (Cox’s Bazar District) area 261.8 sq km, located in between 21°08' and 21°21' north latitudes and in between 92°03' and 92°12' east longitudes. It is bounded by ramu upazila on the north, teknaf upazila on the south, arakan state of Myanmar and naikhongchhari upazila on the east, the Bay of Bengal on the west. Ukhia Upazila has 5 Unions and 54 Village. The average size of population of each union and village are 3600 and 2541 respectively. For study the target area is Raja Palong and Palong Khali. This area distance from capital is 419 km. (Source: Banglapedia)

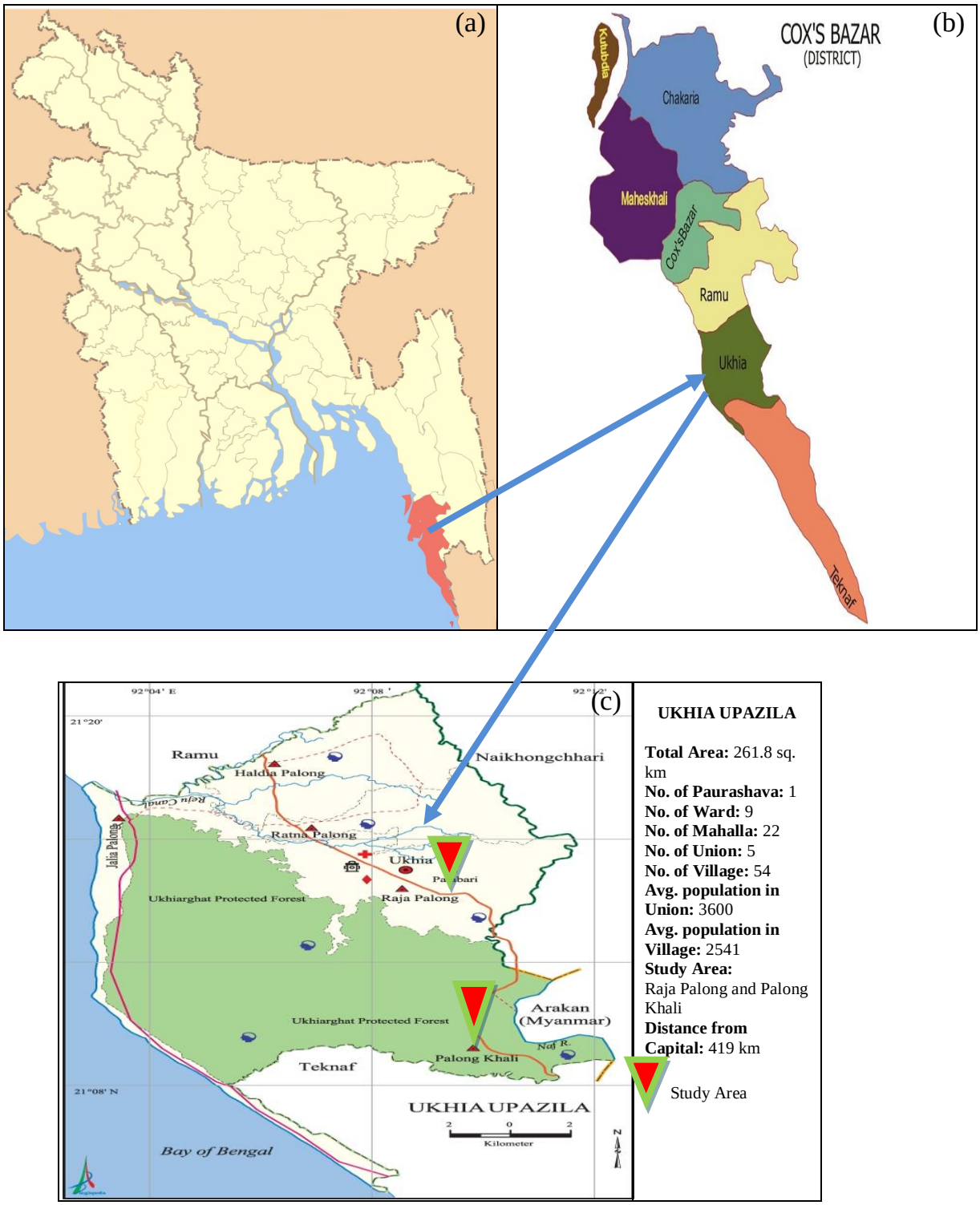

Plate 2: Step wise location of study area where (a) Bangladesh (b) Cox's Bazar District (c) Ukhia Upazila

3.1.2 Topography

Chattogram is very different in terms of topography, with the exception of Sylhet and northern Dinajpur, from the rest of Bangladesh, being a part of the hilly regions that branch off from the Himalayas. This eastern offshoot of the Himalayas, turning south and southeast, passes through Assam and Tripura State and enters Chattogram across the river Feni. The range loses height as it approaches Chattogram town and breaks up into small hillocks scattered all over the town. This range appears again on the southern bank of the Karnafuli River and extends from one end of the district to the other. Chandranath or Sitakunda is the highest peak in the district, with an altitude of 1152 feet above mean sea level. Nangarkhana to the north of Chattogram town is 289 feet high. In the town itself, there is a peak known as Batali Hill, which used to be 280 feet high and was the highest point in the town. (Source: Banglapedia)

According to FAO (1988) Agro-Ecological Zoning, the Cox's Bazar district belongs to the Agro-Ecological Zone (AEZ)-23 (Appendix 1) i.e.; Chattogram Costal Plains containing 3720 Km2 of area. There were four (4) types of land observed in Cox's Bazar district. The organic matter content of the area is low but the fertility level is medium. Out of the total land 17% is high land, 43% medium high land, 13% medium low land and 27% of others.

The highest area in Chattogram division is covered by cropland with declining trend of 1,366,983ha in 1976 to 1,365,756ha in 2000 and further to 1,186,076ha in 2010. Average yearly loss of cropland was 51ha (0.004%) during 1976-2000, 17,968ha (1.32%) during 2000-2010 and 5,321ha (0.39%) during 1976-2010. Forest land is estimated 1,380,402ha, 1,116,258ha and 1,316,104ha in 1976, 2000 and 2010 respectively. Yearly average forest area decreased 9,076ha (0.66%) during 1976-2000 but increased 15,358ha (1.32%) during 2000-2010 and again decreased to 1,891ha (0.14%) during 1976-2010. Yearly average river area increased 0.41%, 0.55% and 0.47% during 1976-200, 2000-2010 and 1976-2010 respectively.

Among non-agricultural lands, rural settlement occupied the largest area that increased more than two-fold during 1976-2010. The data indicates that land gained in rural settlement was 7,266 ha (4.61%), 1,233 ha (0.37%) and 5,491 ha (3.48%) annually during 1976-2000, 2000-2010 and 1976-2000 respectively. Urban and industrial area increased 2.31% during 1976-2010 and 5.73% during 2000-2010. The land gained in urbanization and industrialization was faster during 2000-2010 compared to 1976-2000 and estimated 765 ha annually.

3.1.3 Climatic Zone

The Chattogram lies on 12m above sea level the climate is tropical in Chattogram. Chattogram has significant rainfall most months, with a short dry season. The average temperature in Chattogram is 25.7 °C | 78.2 °F. About 2794 mm | 110.0 inch of precipitation falls annually. The driest month is January. There is 6 mm | 0.2 inch of precipitation in January. In July, the precipitation reaches its peak, with an average of 743 mm | 29.3 inch. With an average of 28.5 °C | 83.3 °F, May is the warmest month. At 19.9 °C | 67.8 °F on average, January is the coldest month of the year. In Chattogram (Bay of Bengal), a water temperature of about 27.20 °C | 80.96 °F is achieved in the annual average. The lowest water temperatures per month are reached in January at around 22.10 °C | 71.78 °F. The average highest water temperatures are around 29.70 °C | 85.46 °F and are measured during October. At about 29.70 °C | 85.46 °F is the maximum water temperature of the year. This is reached around October 05. The minimum value is 22.10 °C | 71.78 °F and is measured around the date of January 17. Slope characteristics of this climatic zone area steeps. This area soils are mainly yellowish brown to reddish brown loams which grade into broken shale or sandstone as well as mottled sand at a variable depth. The soils are very strongly acidic.

Falling between latitudes 20°52’ North and 21.4°09 North, in Cox’s bazar it is within the Tropics of Cancer. The Climate of the following area may be classified into three seasons, namely: spring, which covers the months of March to April, monsoon, which embraces the months of May to October and winter which encompasses the months of November to February. Rainfall occurs frequently and heavily during the monsoon season.

Heavy rainfall occurs in the months of May to October (monsoon period) with monthly depths ranging from 131.1 mm to 941.2 mm. The annual rainfall is 3770 mm. Growth and Development of tropical terrestrial plants and animals are optimal at temperatures ranging from 20 °C. The temperature in Cox's bazar may be classified into three and may also be associated with the three climatic seasons. Dry-hot temperature occurs during the spring season and ranges from 20.8 °C (average minimum) to 32.1 °C (average maximum). Low relative humidity occurs during the spring season and ranges from 27.6% (average minimum) to 98% (average maximum). This area is underlain by sandstone, siltstone and shale of Tertiary and Quaternary ages. The soils developed on these parent materials are brown in colour, usually loamy in texture and very strongly acidic in reaction. Landscape is steep and soils were mainly developed on steep slopes and some occur on more gentle slopes. Natures of parent materials strongly determine the texture of the soils.

3.1.4 Population

Population of Khulshi area 243351; male 56%, female 44%; Muslim 83%, Hindu 10%, Buddhist 2%, Christian 4% and others 1%. Here density per sq. km. is 21237. In this thana, there are 60800 households. Distribution of household by type shows that there are 96.93% general unit, 0.56% institutional and 2.51% other unit. In the thana, 37.1% general households live in pucca house, 30.6% in semi-pucca house, 25.8% in kutcha house and the remaining 6.5% live in jhupri. The average household size (general) for the thana is 4.5 persons as against 4.7 in 2001. (BBS 2013)

According to the 2011 Bangladesh census, total population of Rangunia Upazila was 340000; male 49%, female 51%; Muslim 78%, Hindu 15%, Buddhist 6% and others 1%. There are 67792 households also density per sq. km is 938. Distribution of household by type shows that there are 99.09% general unit, 0.09% institutional and 0.82% other unit. The average household size (general) for the upazila is 4.9 persons, for rural area the size is also 4.9 and for urban area the size is slightly higher i.e., 5.0 persons. In the upazila, 11.0% general households live in pucca house, 9.2% in semi-pucca house, 74.9% in kutcha house and the remaining 4.9% live in jhupri (BBS 2013).

Ukhia area 155187; male 52%, female 48%; Muslim 86%, Hindu 7%, Buddhist 1%, Christian 5% and others 1%. There are 37940 households also density per sq. km is 792. The average household size (general) for the upazila is 5.4 persons, for rural area the size is also 5.4 and for urban area the size is slightly low i.e., 5.0 persons. In this area 8.0% general households live in pucca house, 12.2% in semi-pucca house, 64.4% in kutcha house and the remaining 15.4% live in jhupri (BBS 2013).

3.1.5 Socio Economic Condition

Farmers and farm labourers are major livelihood groups. Agriculture is broadly of two types; hill agriculture (jum) and plain land agriculture (plow agriculture). The number of jum farmers is estimated at 22,413, constituting about 13.4 percent of farm households dependent on agriculture for their livelihoods. Thirty percent of households live on wage labour. Among other agricultural occupational groups are fishers, herdsmen and dairy farmers and poultry keepers. Among non-agricultural activities are weaving, making household utilities, trading, hunting, extracting forest resources, money lending and various salaried jobs. Agricultural activities are either self-financed and/or financed through borrowing. About a quarter of the households borrow from different sources. The highest proportion of them borrows for cultivation of crops. NGOs are a dominant source of credit.

In the coastal zone also, the population is expected to increase from 35.1 million in 2001 to 41.8 in 2015 to 57.9 million by Program Development Office for Integrated Coastal Zone Management Plan Project 2050 (PDO-ICZMP, 2004). Present per capita agricultural land of 0.056 ha will be decreased to 0.025 ha by 2050 (PDO-ICZMP, 2004) On top of this, about 54% people of coastal Bangladesh are functionally landless and over 30% are absolutely landless. Among the landholders, 80% are small farmers, 18% are medium farmers and only 2% are large farmers (PDO-ICZMP, 2004). These have decisive impacts on major economic and livelihood activities, on utilization of land use and subsequently on quality of land. (Community Report, Cox's Bazar District 2011)

The CHT region has a total area of 13,295 km2, 342,390 households and about 1.7 million people. It accounts for 9 percent of the area and 1 percent of the population of the country. CHT is the home to a large number of small ethnic communities with their distinct cultures, livelihoods and identities. The average operated area per household is 0.93 ha (2.30 acres) and that of homestead area is 0.04 ha (0.11 acre). The extent of landlessness is 36 percent. Top five percent households (large farmers) operate 35 percent of the land, while the bottom 25 percent of households operate on only one percent. The extent of poverty is high in the CHT. About half of the population or more are poor. Coping strategies for managing deficits and crises include working as wage labourer, distress sale of household assets, eating less and fewer meals, exhausting savings and fresh borrowing. (Community Report, Chattogram District 2012)

Subsistence farming, small land holdings and short growing season prevail in the region. Most of the farmers grow some fruits and vegetables. Livestock and poultry play an important role in the farming system by supplying meat, milk and egg for nutrition and manure for crop production. Livestock and poultry freely graze. Jumia farmers keep native variety of pigs in their homesteads. Pisciculture is done by those who possess pond or other water body. The majority of farms are of small size. Among all field crops, tobacco is predominant, while among cereal crops; HYV Aman is dominant, followed by HYV Boro and Local Aus (mostly jum variety). Among non-cereal crops other than tobacco, vegetables (both summer and winter), cotton and sugarcane cover substantial areas of the region, as do fruit orchards. Most of the cultivable land (62%) is single cropped. Different farming systems include:

I. Floodplain and valley land irrigated farming system
II. Floodplain and valley land rain fed farming system
III. Upland mono crop-based farming system
IV. Mixed crop-based farming system
V. Upland jum cultivation
VI. Horticulture based farming system in hill slopes

Jum is a traditional farming system in the uplands, which is practiced by local communities and accounts for 10 percent of the net cropped area in the CHT. Cultivating multiple agricultural crops in the cleared patch of hill slopes for one or two seasons and then shifting to another place is a major trait of this land use. Agro forestry is an alternative land use system characterized by cultivating different woody perennials along with agricultural crops.

3.2 Research Design and Data Collection

3.2.1 Research Design

This study conducted descriptive design having both qualitative and quantitative data. To determine the current status of a population, the experiment of collecting data from that population is considered as a survey (Mugenda and Mugenda 1999). Landslide is considered the most destructive hazards in developing countries like Bangladesh, particularly where urbanization and population growth is high, and intensive land use and deforestation or mining practices are going on (Ahmed et al., 2014). In present times there were many causes of the landslide in Chattogram and Cox's Bazar reported by the respondents such as hill cutting, weak soil structure, devegetation, house construction, and steeper hill, of which the major causes were hill cutting, weak soil structure, and devegetation. Therefore, the research design directed the study in seeking to find out the potential application of vetiver grass and their sustainable environmental management on the economic activities of the communities around the study area.

The sampling method of this research is highly purposive to reach our crucial intention. Three distinctive locations (Khulshi, Rangunia, and Ukhia) were selected under two districts of Chattogram and Cox's Bazar. Vetiver availability and different parameters were dissolved to choose these locations. After proper analysis & study of six villages (Lalkhan Bazar, North Pahartoli, Rajanagar, Kodala, Raja Palong and Palong Khali) were spotted roughly where vetiver grass was found and at the same time landslide occurred several times in the last decade. My target was to collect around 140 respondents' observations from those six villages.

All desired data were collected randomly from door to door and addressed as vetiver beneficiary 90, indirect beneficiary 30, and village leader 6 (One from each village respectively). Special inquiry was conducted through the interview with 4 government officers, 4 NGO officers and 6 development agents/social workers (4 from Chattogram and 2 from Cox's Bazar District). The comprehensive data has been visualized through data table 1 stated below.

Table 1: Sample area respondents in hill tract regions

Study Area	**Villages**	**Hill Tract Respondents**				**Govt. and NGO Higher officials & DAs**			**Total Respondents**
		VG Beneficiary	**Indirect Beneficiary**	**Village Leader**	**Total**	**DAE & AEO Officials**	**DAs/ SWs**	**NGO**	
Chattogram	Lalkhan Bazar	15	5	1	21	1	1	1	24
	North Pahartali	15	5	1	21		1		22
	Rajanagar	15	5	1	21	1	1	1	24
	Kodala	15	5	1	21		1		22
Cox's Bazar	Raja Palong	15	5	1	21	1	1	1	24
	Palong Khali	15	5	1	21	1	1	1	24
Total		**90**	**30**	**6**	**126**	**4**	**6**	**4**	**140**

DAs: Development Agents**, SWs:** Social Workers

3.2.2 The following criteria have been proposed after the surveillance of research area:

I. Above mentioned three areas (Khulshi, Rangunia and Ukhia) are mostly hilly and vetiver grass is available at large.
II. The following areas are mostly affected by serious landslide during the rainy season.
III. To assess the potential application of vetiver grass to settle down landslide mishap

3.2.3 Data Collection Tools

Several focus group discussions (FGDs) have been conducted in hilly areas of Chattogram and Cox's Bazar for identifying the vulnerable zones for this research. Both primary and secondary data were collected and used in this research. Primary data was collected through 140 respondents' interview in study areas also secondary data was collected in a different source such as Bangladesh-Thailand vetiver center in Chattogram, research reports, and peer review publications, daily newspapers about landslide & vetiver grass related was used to write up the research paper.

Firstly, we collected primary data set from field experiments in SAU campus planting vetiver grass. Secondly, we collected data from three areas in the hill tract region where there is a common phenomenon for landslide during the rainy season. Data were collected by a survey interview method where the survey was conducted in the selected area on different points of view where the application of vetiver has been successfully implemented. Necessary photographs were collected also at the time of the survey. The interview was conducted with the respondents in their working areas of the following research areas with forty-seven people from each area selected specifically. Here we collected secondary data from Bangladesh-Thailand Vetiver center in Chattogram, research reports, peer-review publications, and daily newspapers.

A questionnaire is a method of gathering information from respondents. For the purpose of this study, a questionnaire was designed to gather information about the Potential Application of Vetiver Grass for Sustainable Environmental Management in Hill Tracts Region Area. Here we try to find out how vetiver grass is helpful for our environment, landslide problems can be solved through their sustainable use that must be environmentally friendly also social-economic activity prospects. When every time the questions were asked to respondents, we carefully considered avoiding influencing the respondent answers to subsequent questions. The time required to complete the questionnaire was kept as short as possible to avoid the fatigue of the respondent which could lead to invalid and unreliable data. A number of open-ended questions were asked to allow respondents to give their own answers. The questionnaire was compiled in English and translated into Bangla to enable respondents to answer questions in their first language.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

Plate 3: Above pictures (a) and (b) showing VG plantation, (c) showing VG Nursery (d) and (e) showing VG maintenance, (f) showing handicraft materials made by VG (g) and (h) showing data collection from the respondents by using questionnaire

3.2.4 Experimental Field Data

The experiment was carried out in Agroforestry farm, Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University. The experimental site is medium high land in the Agro-Ecological zone of Madhupur Track (AEZ no.28). The plot size was length 3m x width 1.5m. The land is prepared for vetiver plantation at 19th September 2018 and 20th September 2018. The land is plowed to a depth of 20-25 cm by 2-3 deep ploughings and removes the perennial weeds. In field row to row and plant to plant distance 60 cm x 30 cm. A number of vetiver tillers have been collected from the International University of Business Agriculture and Technology (IUBAT) campus and the rest from the Rajshahi district then transplanted it in Sher-e-Bangla Agricultural University (SAU) research plot.

The natural growth of vetiver plants has been observed without any application of organic or chemical fertilizer. Vetiver plantation was implemented on 26th September 2018. The mother clumps divided into too small pieces to give many numbers of slips. Slips were separated from the clump with the rhizome portion intact having 15-20 cm of the shoot portion. At the time of planting slips fibrous roots and leaves were trimmed off. Plantation of vetiver was performed vertically about 10 cm deep. Row to row and plant to plant distance was 60 cm x 30 cm.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

Plate 3: Above pictures (a) showing land preparation for VG plantation (b) showing VG seedling plantation (c), (d), (e) and (f) showing VG field visit and data collection (g) showing up rooting hole VG plant (h) showing measuring VG dry weight from SAU Agroforestry field

3.2.5 Data Analysis

Data analysis is a process of inspecting, cleansing, transforming, and modelling data with the goal of discovering useful information, informing conclusions, and supporting decision-making. Here collecting all data from interviewed, questionnaires were checked for its completeness, correctness. In this survey, qualitative and quantitative data were collected from the field. Questionnaires were coded by me and information obtained through the questionnaire was 36 analysed by Microsoft Excel Worksheet & SPSS V27 software. Open-ended and close-ended data were 36 analysed through those programs. Data were collected based on the respondent's general information including name, age, gender, educational qualification, marital status, and family size. In addition, data were taken on the basis of the respondent's knowledge of vetiver grass. According to the topic related points counted and then entered into the computer for analysis.

CHAPTER 4
RESULTS AND DISCUSSION

A consecutive and itemized discussion on the findings of the study has been presented in this Chapter. This Chapter is divided into six segments. In the first one, we have mentioned general information of the respondents' briefly so it becomes easy to understand the socio-economic condition and the inheritance of the people involving cultivation in these locations. In the second segment, we have found to assess the potential application of vetiver plantation in the research area. The geographical location of research areas and its' characteristics are described in Chapter 3. Then we identified the practices followed for mudslide and soil erosion control for environmental management which has been included in the third segment. This segment also highlights the most important parts of the project for developing vetiver grass in the targeted locations. The fourth portion deals with the people's participation in the adoption of the vetiver plantation in the research area including the Government's and NGO's contributions, achievements and overall performances. Some significant limitations and uncertain conditions have been brought to light while collecting data from respondents. In the next segment, we have tried to find out the pros and cons of social development and the impact of vetiver plantation in the research area whether they can prosper or not by learning multipurpose use of vetiver grass. Their intellectual opinions are also brought under consideration for making a better vetiver plantation, management, and marketing experience. Finally, we have compared the growth performance of vetiver grass between the research areas and research field.

4.1 General Information of the Respondents'

4.1.1 Different gender group

Pie Chart shows the percent s of the respondents in accordance with their gender. Notice that, most of the respondents are male. Here, 67% of respondents are male and 33% of respondents are female.

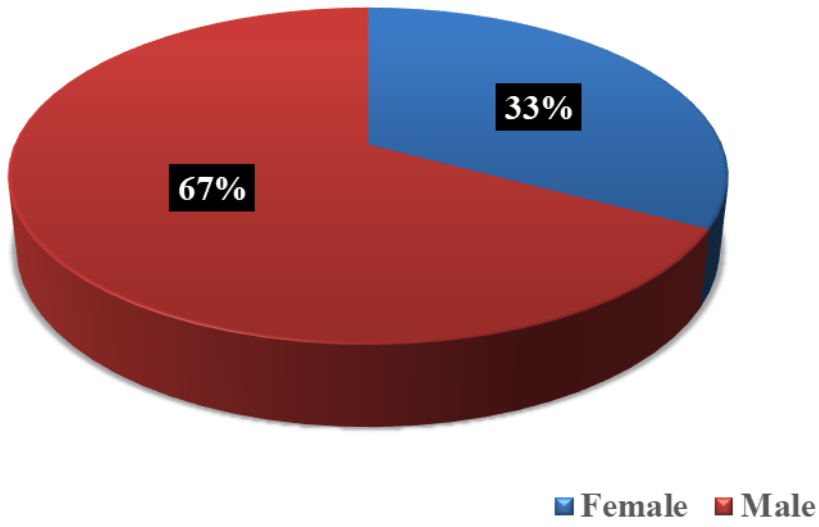

Figure 1: Pie chart showing different gender group of the respondent in study area

4.1.2 Different Age of the Respondents

In case of the age distribution of the respondents, we divide it into five ranges as 18-25 years, 26-35 years, 36-45 years, 46-60 years, and >60 years. The highest number of respondents found having the age range of 36-45 years and the lowest number found in the range of >60 years.

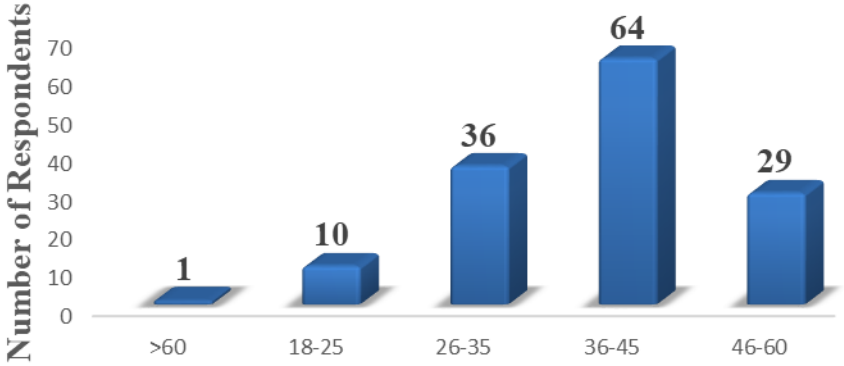

Figure 2: Bar chart showing different age of the respondents in study area

4.1.3 Level of education

The level of education of a respondent was measured by the level of his/her formal education. The highest proportion 29% of the respondents had secondary, whereas 24%, 23%, 14%, 7% and 3% of them had more educated then secondary, can't read and write, primary, read and write, last one sign only respectively.

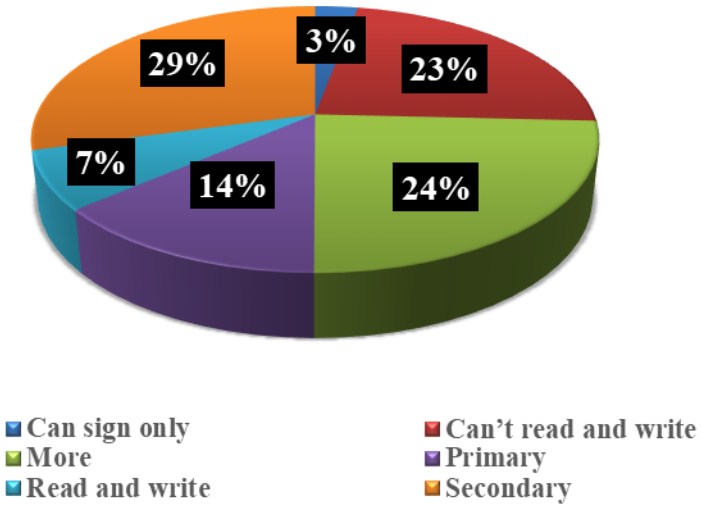

Figure 3: Pie chart showing the respondents level of education in study area

4.1.4 Family Size

Families are divided into four ranges from 1-2, 3-4, 5-6 and>6. According to the information, most of the family found 5-6 members. Comparably there was a lower number in family size having 1-2 members.

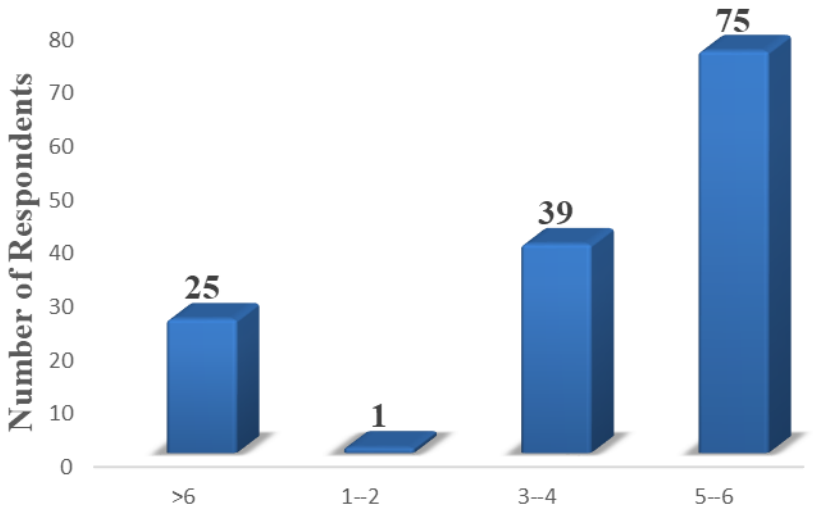

Figure 4: Bar chart showing the respondents family size in study area

4.1.5 Occupation

Different types of people having different professions or occupations living in this research area. To know about the occupation of the respondents, it was divided into six categories for example farmer, fishermen, businessman, labourer, government employee, and others. Most of the respondents were farmers and the lowest number respondent was a fisherman.

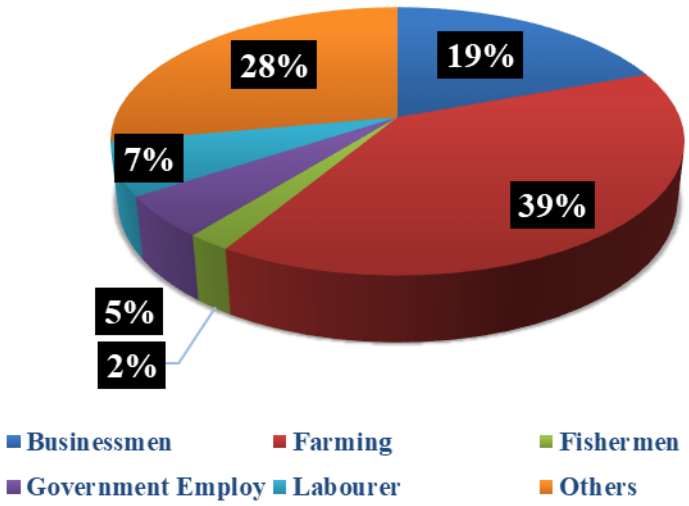

Figure 5: Pie chart showing the respondents occupation in study area

4.2 To assess the potential application of vetiver plantation in hill tracts region

4.2.1 Respondent's general knowledge on vetiver grass

Generally, the research indicates that all the respondents of the research area were familiar with vetiver grass. They are also aware of the growing area where vetiver grass grows most in their area.

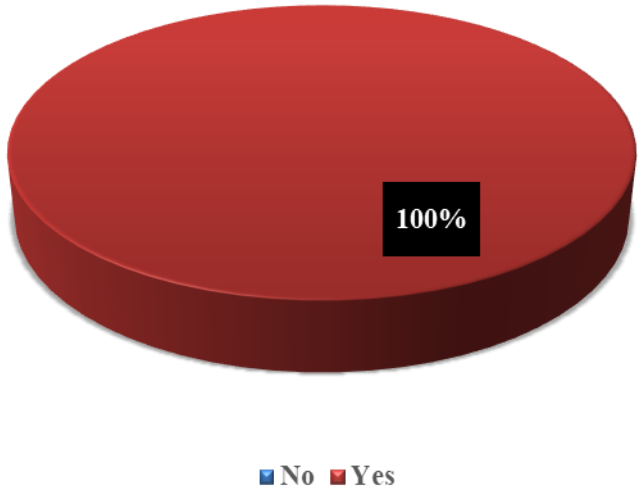

Figure 6: Indirect and Direct Respondents – Pie chart showing the respondents general knowledge on vetiver grass

4.2.2 Respondents' uses of the household activities mostly

In addition, respondents were asked to give their views on the possible uses of vetiver grass in their area. All of them gave their own views and opinions but after sorting their views and opinions we found that majority of the respondents said vetiver grass use as mainly livestock bedding material in their area. They also added some more uses, for example, thatch roof, fencing, green/biomass fuel, wall hanging, low-cost storage bin, and others.

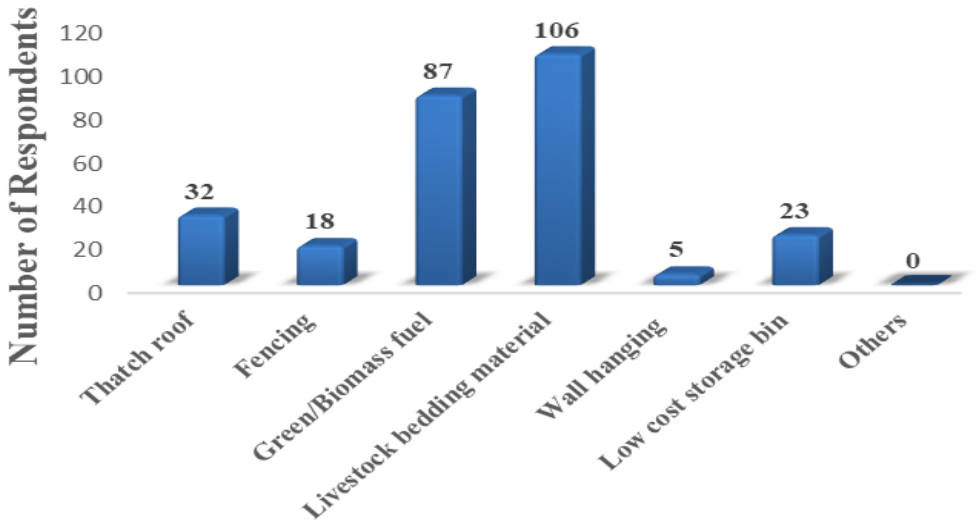

Figure 7: Indirect and Direct Respondents – Bar chart showing the respondents uses of the household activities mostly

4.2.3 Respondent's use of vetiver grass for the improvement of agricultural practice

The indirect graph shows that the maximum number of respondent's not sure about the improvement of agricultural practice by using vetiver grass because they are not working in the field to plantation vetiver grass. On the other hand, the direct graph shows that the maximum number of respondents have knowledge about the improvement of agricultural practice by using vetiver grass because they are directly involved in plantation and maintenance of the vetiver grass.

Moreover, Nix *et al.*, (2006) evaluated the effect of using vetiver grass roots as soil mulch to act against the same subterranean termites. In this study, vetiver root mulch (with a root to sand ratio of 25% in mass) proved to reduce termite tunneling activities/wood consumption and increased termite mortality.

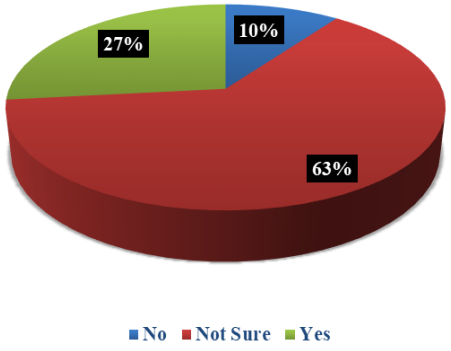

Figure 8: Indirect Respondents – Pie chart showing improvement of agricultural practice in the study area

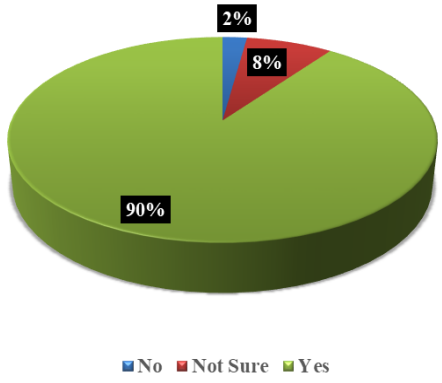

Figure 8 (a): Direct Respondents - Pie chart showing improvement of agricultural practice in the study area

4.2.4 Use of vetiver grass in the farm

Respondent gave their opinion were the vetiver grass is mostly used as vetiver compost and fodder on the farm after that they are used vetiver grass as field boundary according to soil conservation, mulching/moisture retention, insect repellents, and bioremediation respectively.

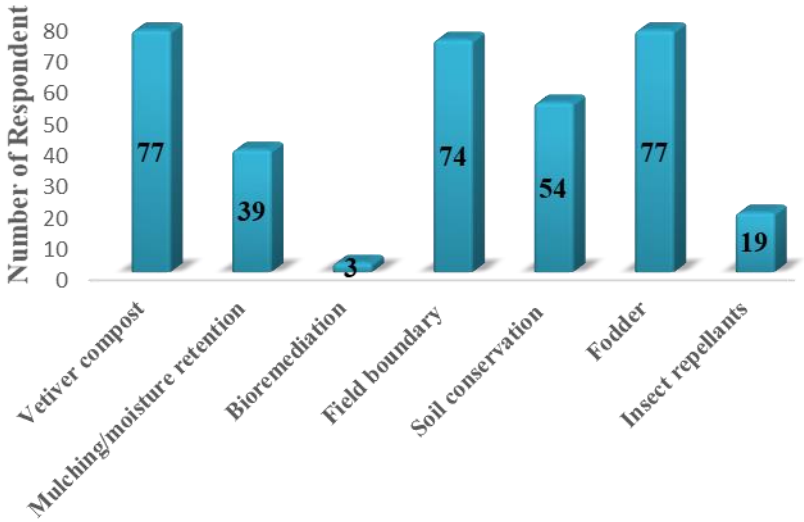

Figure 9: Indirect and Direct Respondents – Bar chart showing use of vetiver grass in the farm in study area

4.2.5 Use of vetiver grass for hill tract protection

Vetiver grass is used for structural strengthening in the hill tract region. In the research area, most of the respondent's opinion about hill protection through vetiver grass is positive. Maximum respondents are given their opinion about hill slop protection also mudslide control happened through vetiver grass plantation. Beside vetiver grass can be used as earth embankment, hilly settlement, and more purpose.

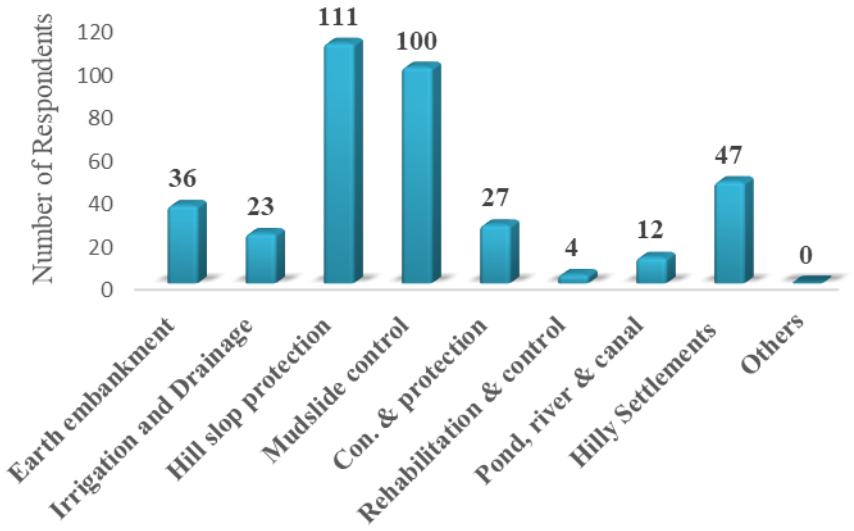

Figure 10: Indirect and Direct Respondents – Bar chart showing use of vetiver grass for hill tract protection in study area

4.2.6 Use of vetiver grass for industrial commodities

Asked the respondents whether vetiver grass can be as any kind of industrial purpose or not and gave them three options of yes, no, and not sure. An indirect pie chart indicates 80% of the respondents gave a negative answer by saying no and not sure while 20% gave a positive answer saying yes. Again, the indirect pie chart indicates 54% of the respondents gave a positive answer by saying yes while 46% gave a negative answer saying not sure.

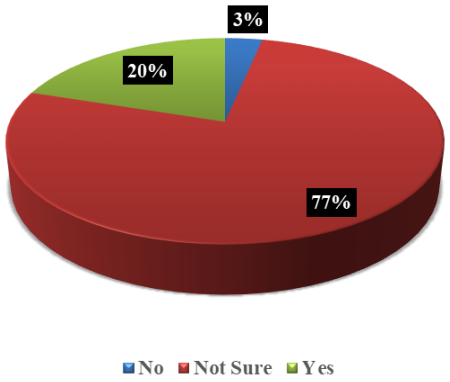

Figure 11: Indirect Respondents – Pie chart showing use of vetiver grass for industrial commodities in study area

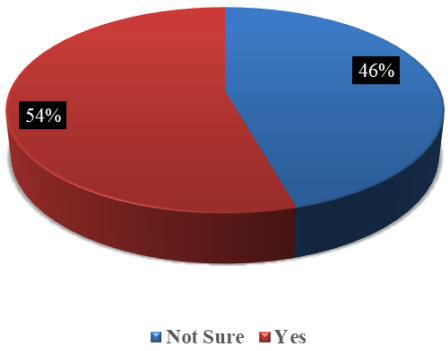

Figure 11 (a): Direct Respondents - Pie chart showing use of vetiver grass for industrial commodities in study area

4.2.7 Use of vetiver grass for mudslide control in study area

Babola *et al.,* (2003) indicated that several aspects of vetiver make it an excellent erosion control plant in warmer climates. Rows of plants oriented perpendicularly to the slope direction has used as semi permeable barriers that reduce the surface runoff, amount of infiltrated water increases and the runoff and soil loss amounts decrease. This makes vetiver an excellent stabilizing hedge for stream banks, terraces, and rice paddies and protects soil from sheet erosion.

We sought information on whether vetiver grass helps to control mudslide, increase or decrease structural strengthening of soil or not and gave them two options of yes and no. All the respondents indicated in the positive reaction by saying yes and none of the respondents found with a negative reaction.

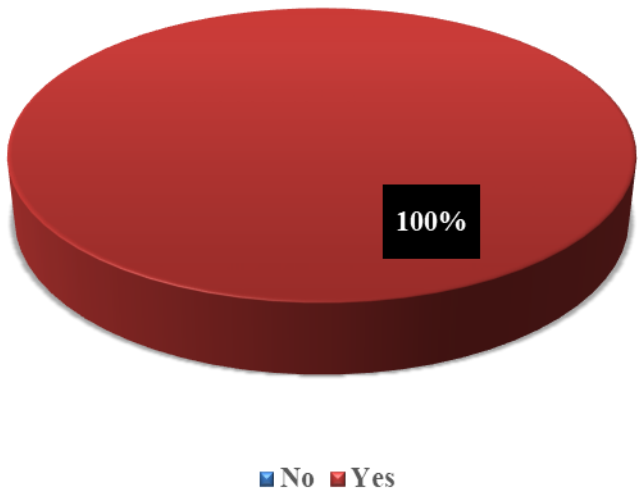

Figure 12: Indirect and Direct Respondents – Pie chart showing the use of vetiver grass for mudslide control in study area

4.2.8 Various techniques for mudslide control

According to the respondents, due to continuous mudslides, various problems have arisen. Nowadays soil erosion problems also one of them. There are various techniques for mudslide control. According to the respondents, they told that by plantation vetiver grass, retaining wall, tree and native vegetation, sandbags and straw wattles, geo jute installing and installing a pile can control mudslide.

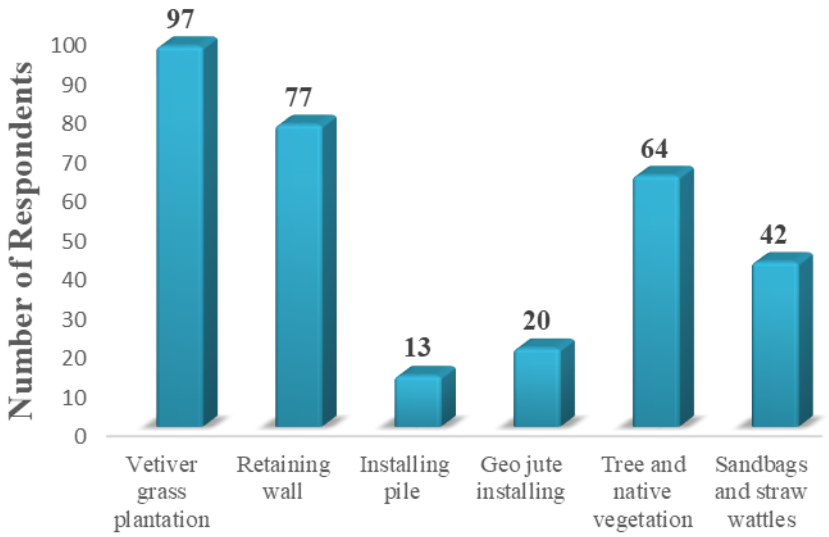

Figure 13: Indirect and Direct Respondents – Bar chart showing the various techniques for mudslide control in study area

4.2.9 Purpose of vetiver grass for use on respondent's plot

From this survey data, most of the respondents used their own plot as a purpose of planting vetiver grass for controlling soil erosion, soil conservation, slope stabilization, landslide stabilization, and terrace formation, fodder, and border demarcation. About 76 respondents used vetiver grass for slop stabilization; about 64 respondents used vetiver grass for land slide stabilization, about 52 respondents used vetiver grass for soil conservation, 50 respondents used vetiver grass for erosion control and 33 respondents gave their opinion about fodder purpose for using vetiver grass on their plot.

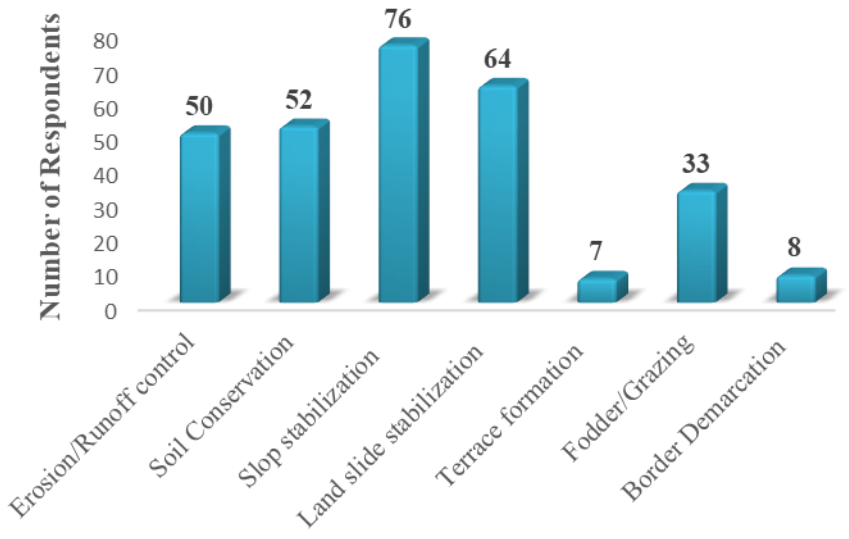

Figure 14: Indirect and Direct Respondents – Bar chart showing the purpose of vetiver grass for use on respondents plot in study area

4.2.10 Plantation of vetiver grass can fight more effectively in research area for disaster risk management

It is essential to embed how the vetiver grass fights more effectively for disaster risk management in the study area, and therefore the respondents were asked several questions. Whether vetiver grass fights more effectively for disaster risk management, where most of the respondents gave a response by saying yes and the highest response found inland stabilization and lowest was a natural barrier against fire events.

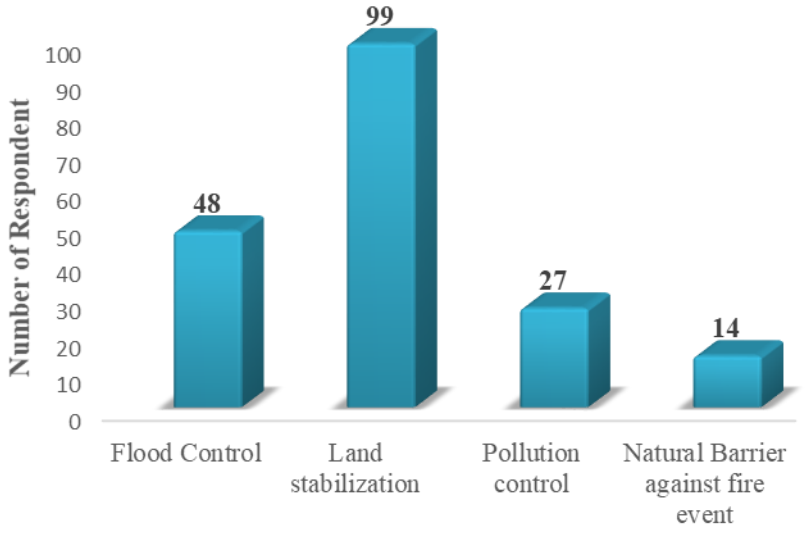

Figure 15: Indirect/Direct – Bar chart showing plantation of vetiver grass can fight more effectively in research area for disaster risk management in study area

4.3 To identify the practices followed for mudslide and soil erosion control for environmental management

4.3.1 The observation of specific practices for vetiver plantation with other associated components

The indirect pie chart shows that most of the respondents are not sure about the specific practices for vetiver plantation with other associated components. Besides direct pie chart indicates most of the respondents known to the specific practices for vetiver plantation with other associated components. Here the observation is direct respondents are directly involved in vetiver plantation on the other hand indirect respondents are not directly involved in vetiver plantation.

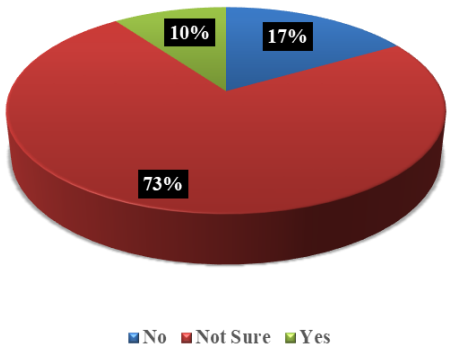

Figure 16: Indirect Respondents – Pie chart showing specific practices for vetiver plantation with other associated components in study area

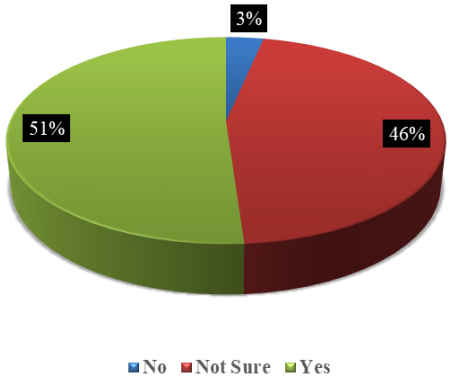

Figure 16 (a): Direct Respondents - Pie chart showing specific practices for vetiver plantation with other associated components in study area

4.3.2 The practicing of slope protection technique in Rohingya settlement area as an environmental management tool

Among the indirect respondents, 63% gave a positive opinion, and 37% not sure about the practicing of the slope protection technique in the Rohingya settlement area as an environmental management tool. Besides direct respondent's 83% gave a positive response about the slope protection technique in the Rohingya settlement area, 15% not sure about this technique and 2% gave a negative response. In Rohingya settlement area is mostly practiced geo jute technique, retaining wall, bare terrace, sandbags, and straw wattles.

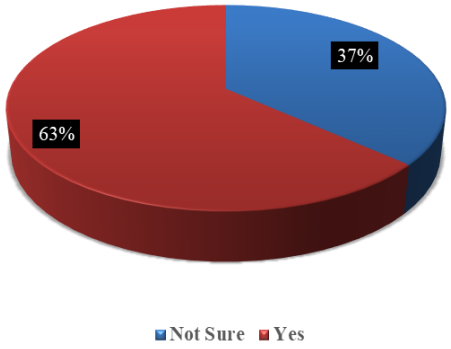

Figure 17: Indirect Respondents – Pie chart showing the practicing of slope protection technique in study area

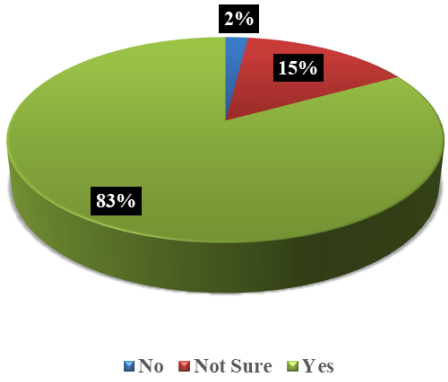

Figure 17 (a): Direct Respondents - Pie chart showing the practicing of slope protection technique in study area

4.3.3 Conception of the respondents about vetiver hedgerow reduce soil erosion and runoff water, increase soil fertility and moisture than any other engineering methods

The outcome of this question indicated that vetiver is best and effective when planted in rows on land and has been used successfully for flood and soil erosion control. In this case all respondents agreed vetiver grass has the capacity to reduce soil erosion and runoff water, increase soil fertility and moisture than any other engineering methods.

Table 2: Vetiver hedgerow reduces soil erosion and runoff water, increase soil fertility and moisture than any other engineering methods

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	111	92.5	92.5	92.5
	Disagree	1	1.1	1.1	93.6
	Strongly agree	8	6.4	6.4	100.0
	Total	120	100.0	100.0	

4.4 To evaluate people's perception on adoption of vetiver plantation in hill tracts region

4.4.1 Introduced vetiver grass in study area

Indirect pie chart showed introduced vetiver grass in the study area 64% of the respondents said NGOs, DAs again 33% of respondents told Govt., DAs, and lastly 3% respondents. On the other hand, a direct pie chart showed vetiver grass introduced in the study area maximum of 42% respondents told NGOs DAs, Govt. DAs and the lowest number were 7% it was Govt. DAs.

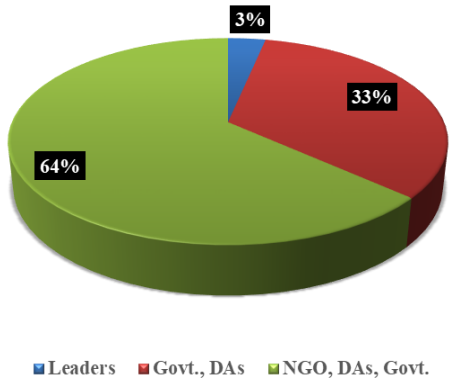

Figure 18: Indirect Respondents – Pie chart showing vetiver grass introducer in study area

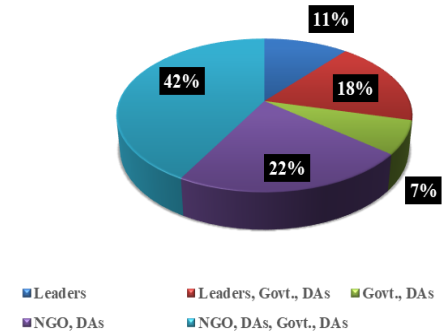

Figure 18 (a): Direct Respondents - Pie chart showing vetiver grass introducer in study area

4.4.2 Duration of people's adoption vetiver plantation in study area

As per the bar chart indirect and direct, the majority of the respondents agreed that vetiver grass was adopted 6-10 years in the study area. Respondents are well known this grass in many years back but they have properly adopted this grass in 6-10 years only.

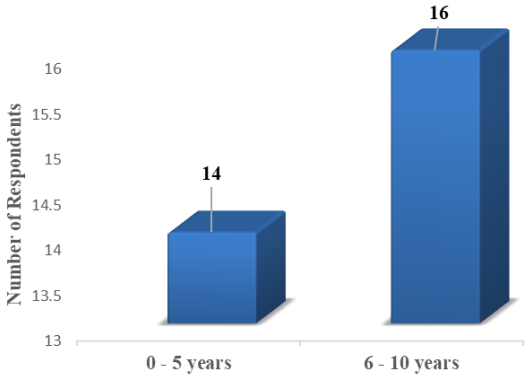

Figure 19: Indirect Respondents - Bar chart showing duration of people's adoption vetiver plantation in study area

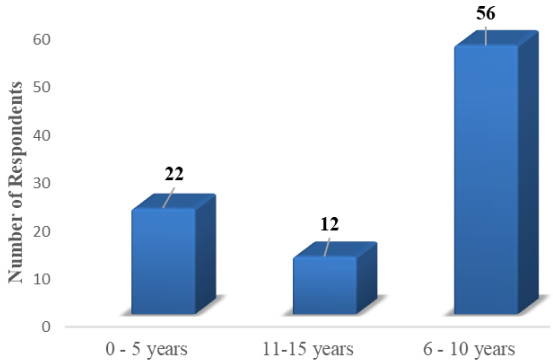

Figure 19 (a): Direct Respondents – Bar chart showing duration of people's adoption vetiver plantation in study area

4.4.3 Popular planting material for vetiver plantation in study area

The respondents pointed out that vetiver grass is being propagated mainly by root division in the study area. Splitting tillers from a mother clump and each slip included at least two to three tillers and a part of the crown. After separation, the slips were cutback to make it appropriate for the plantation. Almost all framers in the study area who used vetiver grass for soil and water conservation were using this easy method of propagation.

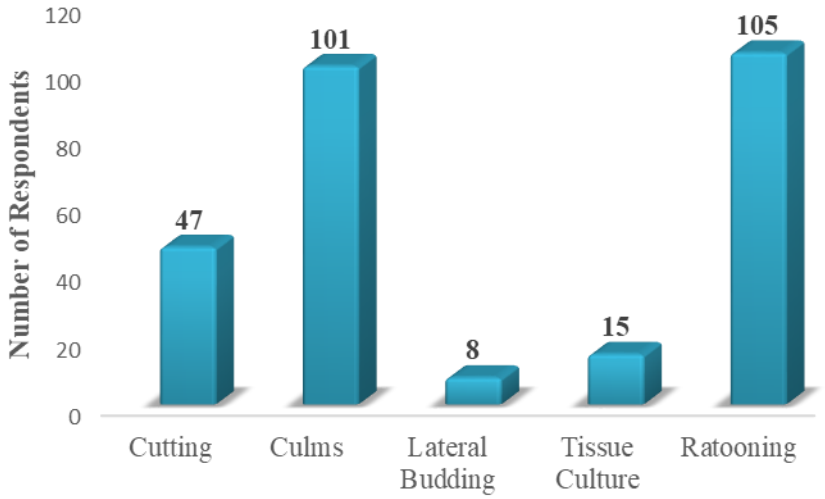

Figure 20: Indirect and Direct Respondents – Bar chart showing popular planting material for vetiver plantation in study area

4.4.4 Methods were used in introducing vetiver grass for environmental management purpose

This study found a maximum of 103 respondents said demonstration sites visit is the best methods were used in introducing vetiver grass for environmental management purposes. After demonstration sites visit, field visit, and training program both were effective methods in introducing vetiver grass in the study area.

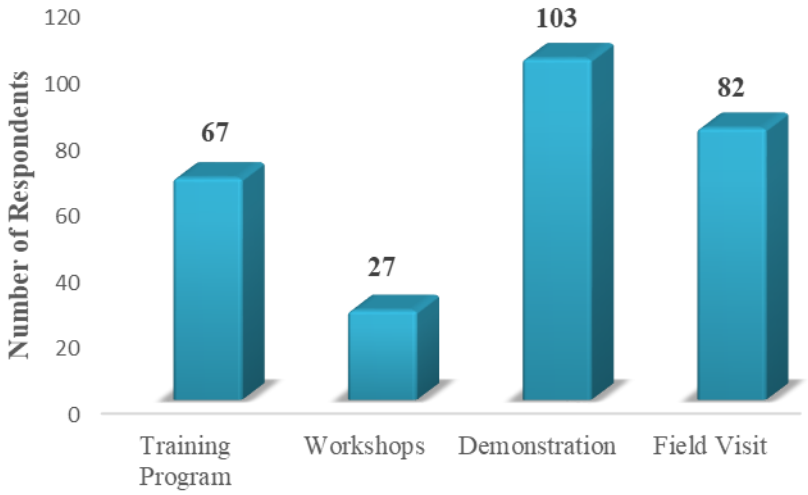

Figure 21: Indirect and Direct Respondents – Bar chart showing methods were used in introducing vetiver grass for environmental management purpose in study area

4.4.5 Invasiveness test for vetiver grass

According to the respondent, there was no other plant that can grow faster in any kind of soil type and weather condition and appropriate for conservation like vetiver grass. Both indirect and direct respondents, 7% gave negative views about vetiver grass as a weed in the study areas. The maximum number of the respondents gave a positive opinion against vetiver grass as weed or any invasive characteristics.

According to U.S. National Academy of Sciences (1993) it is critical that any plant used for environmental protection is not invasive and will not become a weed. The South Indian form of vetiver is not considered a weed in the dozens of places where it has been planted.

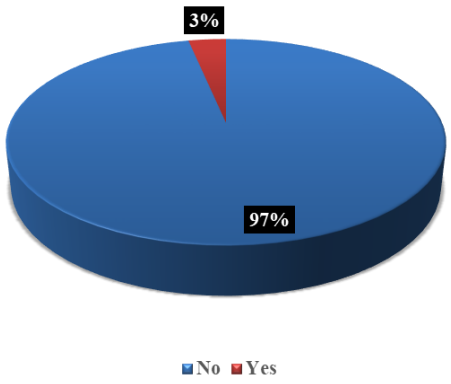

Figure 22: Indirect Respondents – Pie chart showing invasiveness test for vetiver grass in study area

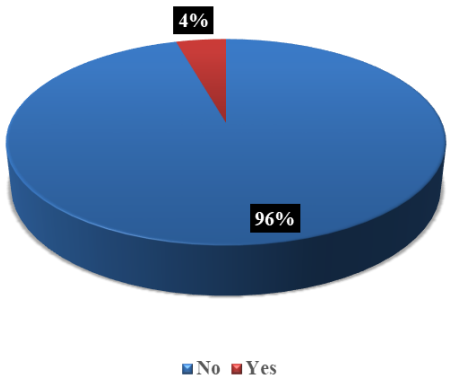

Figure 22 (a): Direct Respondents - Pie chart showing invasiveness test for vetiver grass in study area

4.4.6 Use of vetiver grass as animal feed and respondent's interest in using nutritious animal feed made by tender vetiver grass shoot

According to the questionnaire, there were two options yes or no that given to the respondents to know whether vetiver grass use as animal feed in their area or not. All of the respondents came up with the positive option that vetiver grass uses animal feed in their area.

Anon *et al.*, (1990) reported that the young vetiver leaves can be ground to feed fish and livestock, but mature leaves cannot be used for such purposes because their nutritive value is lower than other grasses, and because of the high roughness and silica content. The analysis also indicated that vetiver has the content of crude protein lower than that of other grasses used for animal feed.

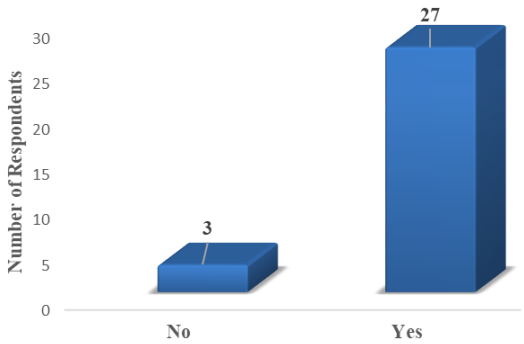

Figure 23: Indirect Respondents – Bar chart showing use of vetiver grass as animal feed in study area

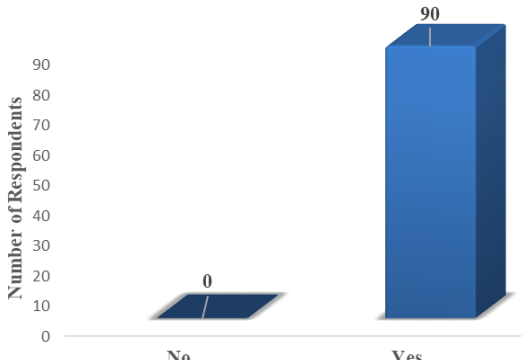

Figure 23 (a): Direct Respondents - Bar chart showing use of vetiver grass as animal feed in study area

4.4.7 Pest and disease management at vetiver plantation site

Accordingly, most of the household was using vetiver hedges to protect their properties from the attack of rodents, snakes, and ants. As per the bar chart shows, the majority of the respondents agreed that vetiver grass manages pest and disease.

According to Lal (1981) and Aina (1989) vetiver can be used for crop protection of. physical and biological measures of erosion control such as contouring, tillage, soil mulching, terracing, alley-cropping, agroforestry, crop rotation etc.

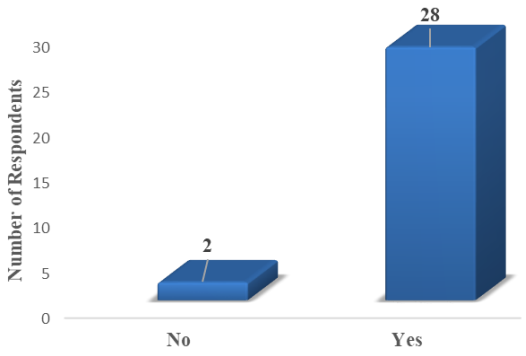

Figure 24: Indirect Respondents – Bar chart showing pest and disease management at vetiver plantation site

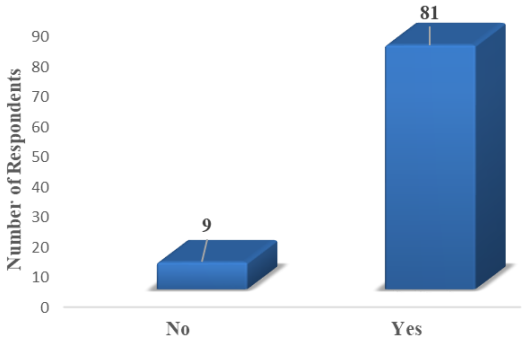

Figure 24 (a): Direct Respondents - Bar chart showing pest and disease management at vetiver plantation site

4.4.8 Outgiving properties of vetiver grass plantation practice as an eco-friendly and climate smart mitigation strategies for disaster risk management

Vetiver grass deep, massive and fibrous root system grows vertically deep into the soil and forms a tightly knitted net and anchor a hedge firmly and binding the soil. This root system makes vetiver grass an eco-friendly unique and useful plant on earth to control disaster risk management. Here bar chart showed the maximum number of respondents says yes about vetiver grass plantation practice as an eco-friendly and climate-smart mitigation strategies for disaster risk management.

Thomas *et al.*, (2002) presented the trials of vetiver grass on 28 km of embankment project built on the Kangsha River in Netrokona District under Dampara Water Management Project (DWMP) in 2000. DWMP demonstration sites proved that the vetiver grass provides outstanding protection against erosion while also being a sustainable supply of fodder and thatch.

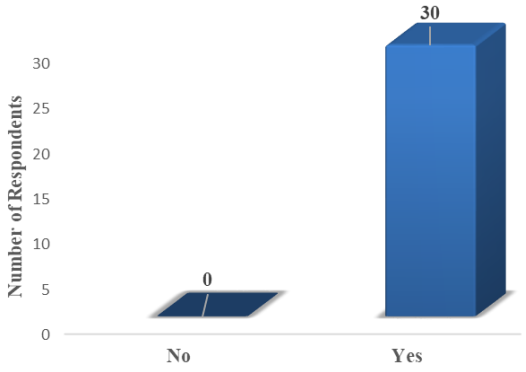

Figure 25: Indirect Respondents – Bar chart showing vetiver grass plantation practice as an eco-friendly and climate smart mitigation

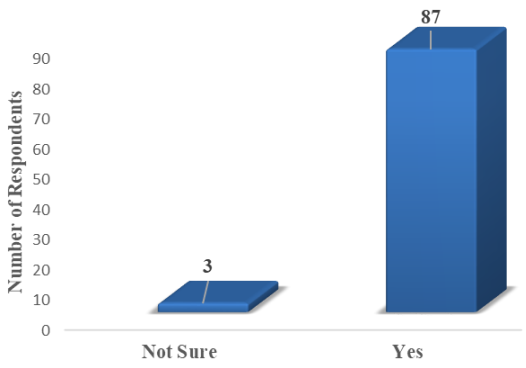

Figure 25 (a): Direct Respondents - Bar chart showing vetiver grass plantation practice as an eco-friendly and climate smart mitigation

4.4.9 Tolerance capability of vetiver grass in extreme environmental stress like temperature, drought, flood, and other natural disaster

Vetiver grass had highly tolerant soil high in acidity, alkalinity, salinity, and others. It regenerates rapidly following drought, fire, flood, and other adverse conditions. The pie chart indicates vetiver grass has tolerant extreme environmental stress.

Vetiver grass has a deep thick root system which spreads vertically rather than horizontally, which allows it to efficiently endure harsh conditions (Maneecharoen *et al.*, 2013).

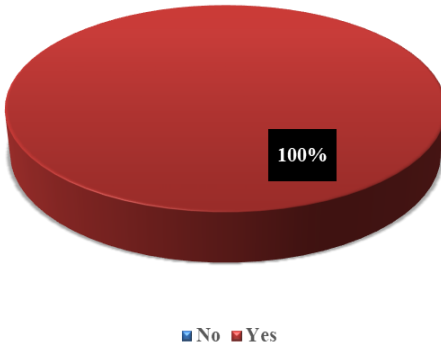

Figure 26: Indirect Respondents – Pie chart showing tolerance capability of vetiver grass

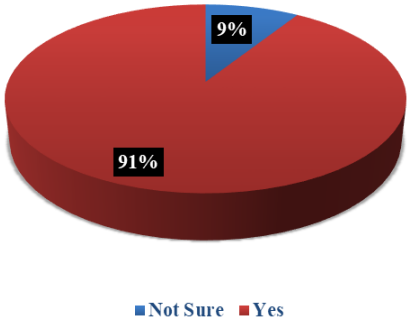

Figure 26 (a): Direct Respondents - Pie chart showing tolerance capability of vetiver grass

4.4.10 Availability of vetiver grass

According to the respondent's vetiver grass availability is high. Because vetiver grass grows naturally in the study area also supply by the government and NGOs to the respondents. Rahman *et al.*, (1996) proposed that Bangladesh has an abundant supply of vetiver grass. It is commonly found in almost all the districts. While mapping available places of vetiver grass in Bangladesh, they found that vetiver grass is available in 85% of the total land. Naturally grown vetiver grass found in Kuakata, Pubail, Haor and hill track regions in a very large portion. It was also claimed that Soil of Kuakata and Haor area is salty sand (SM) while the soil of Pubail is silty clay (CL) which means that vetiver can grow in both types of soils. Countrywide study is yet to be done to have a clear profile of availability and uses of vetiver.

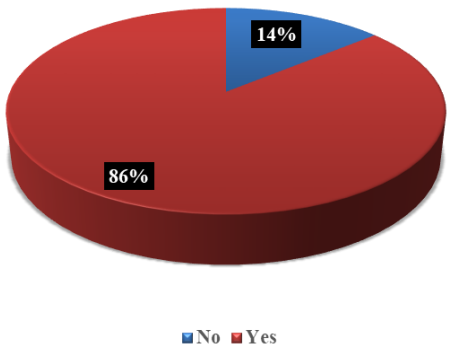

Figure 27: Indirect Respondents – Pie chart showing availability of vetiver grass in study area

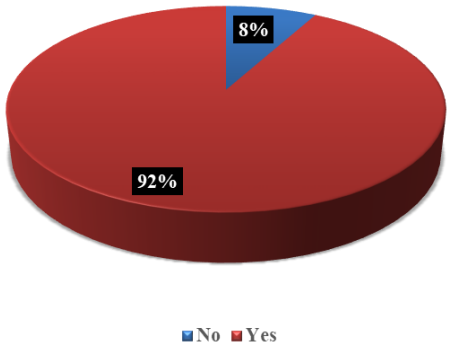

Figure 27 (a): Direct Respondents - Pie chart showing availability of vetiver grass in study area

4.4.11 Respondents' opinion about soil for vetiver grass establish

Grows best on deep sandy soils, respondents were also asked to express their opinion about the soil type for vetiver grass establishment most of the respondents agreed with sandy and silt type soil is more preferable for planting vetiver grass.

According to Alemu Mekonnen (2000) Vetiver grass thrives in arid and humid conditions (annual rainfall of 300 to 3000 mm) and grows successfully on variety of soils such as shallow, rocky, acidic and saline, with no particular limitation but in our findings, we found all the respondents indicating sand, silt, clay and diverse soil are favorable for vetiver plantation.

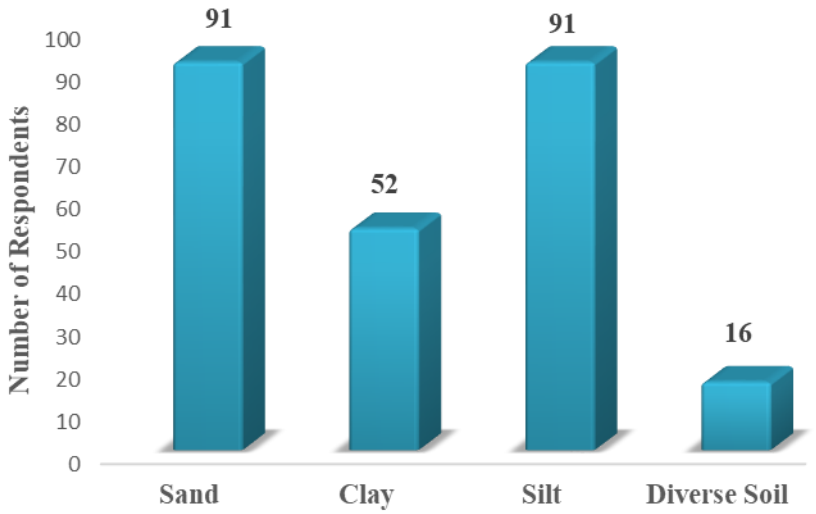

Figure 28: Indirect and Direct Respondents – Bar chart showing respondents opinion about soil for vetiver grass establish in study area

4.5 To justify the social development in hill tracts region by vetiver plantation

4.5.1 Acceptance of vetiver grass plantation systems as an eco-friendly tool for social development in hill tract region

According to Habtamu *et al.,* (2009) Income and livelihood diversification is one of the several strategies available to enhance social resilience in the face of climate change. On top of its ecological services, vetiver is used as fodder and fiber and generates income for local communities. Its leaves and roots can be used for other purposes (especially its leaves), which usually have to be cut to keep the vetiver rows in order and can be used for roofing as well as making handicraft products to earn extra income.

It is essential to embedded how the acceptance of vetiver grass plantation systems as an eco-friendly tool for social development in the study area, and therefore the respondents were asked questions. Whether vetiver grass used as a social development tool or not- to know this information we offered them two option of yes and no, where most of the respondents gave responses by saying yes.

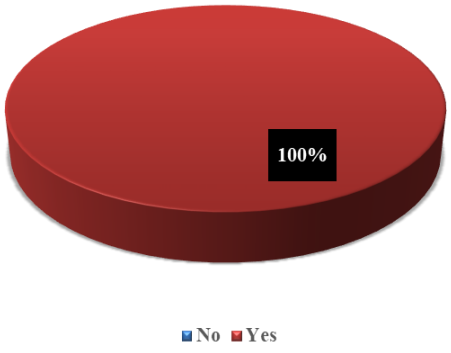

Figure 29: Indirect Respondents – Pie chart showing acceptance of vetiver grass plantation systems

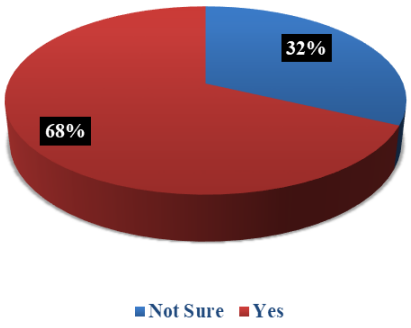

Figure 29 (a): Direct Respondents - Pie chart showing acceptance of vetiver grass plantation systems

4.5.2 Sufficiency of vetiver grass for socio economic development in hill tract region

In addition, respondents were asked to give their views on the sufficiency of vetiver grass for socio-economic development their area. All of them gave their own views and opinions but after sorting their views and opinions we found that the majority of the respondents said vetiver grass not a sufficient tool for socio-economic development in the study area.

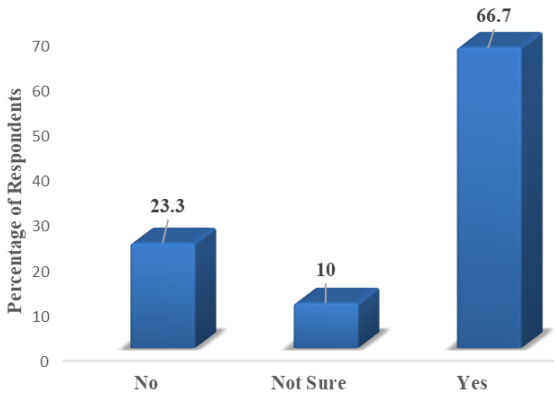

Figure 30: Indirect Respondents – Bar chart showing sufficiency of vetiver grass for socio economic development in hill tract region

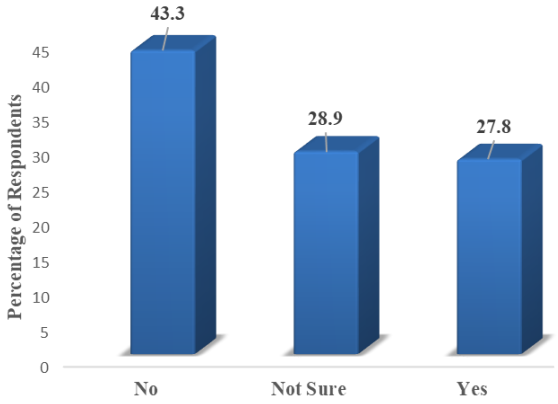

Figure 30 (a): Direct Respondents - Bar chart showing sufficiency of vetiver grass for socio economic development in hill tract region

4.5.3 Suggestion of the respondents on some important key tactics for successful adoption of vetiver grass in hill tract region for overall social development

In addition, respondents were asked to give their views on some important key tactics for successful adoption of vetiver grass in the hill tract region for overall social development. All of them gave their own views and opinions but after sorting their views and opinions we found that majority of the respondents said awareness, sustainable policy, government, NGOs support, and technical support are important key tactics for successful adoption of vetiver grass in hill tract region for overall social development.

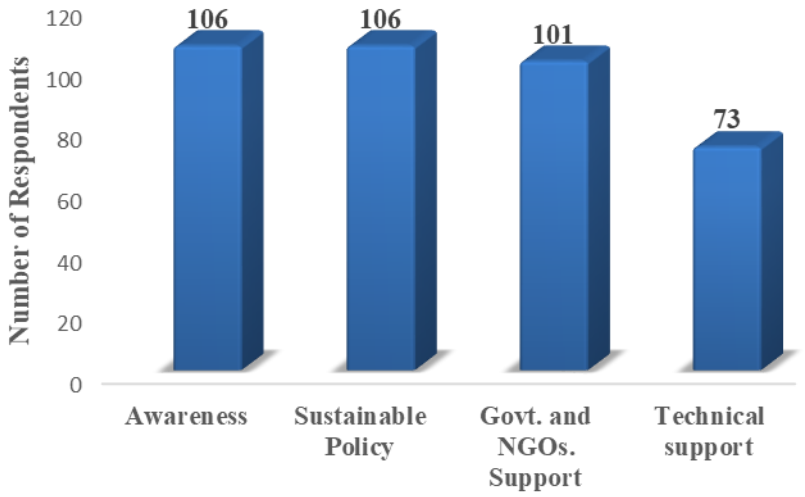

Figure 31: Indirect and Direct Respondents – Bar chart showing successful adoption of vetiver grass in hill tract region for overall social development

4.6 To examine the growth character of vetiver grass for environmental management strategy

Table 3: Sample data collected from research area and SAU campus

Date	Area	Plant Height (CM)	Root Length (CM)	Tillering No.
24.08.20	North Pahartali	283	23	73
25.08.20	Rangunia	298	27	75
26.08.20	Ukhia	272	20	71
13.12.19	SAU Campus	244	18	68

The following tables highlight a massive comparison of vetiver grass between research field and research areas. This analogy shows the possibilities, perspectives, and limitations of vetiver plantation in our country. We can also identify and compare our results with other countries like Nepal, Srilanka, India who are already using vetiver grass for various purposes successfully for quite a long ago. The following tables reflect a clear perception of vetiver hedge development and management in different conditions.

The natural growth of vetiver plants has been observed without any application of organic or chemical fertilizer. Vetiver plantation was implemented on 26th September 2018. The mother clumps divided into too small pieces to give many numbers of slips. Slips were separated from the clump with the rhizome portion intact having 15-20 cm of the shoot portion. At the time of planting slips fibrous roots and leaves were trimmed off. Plantation of vetiver was performed vertically about 10 cm deep at a spacing of 60×30 cm. During the initial period of plant growth, 2-3 weeding and earthing-up were done at an interval of everyone month. Intelligent application of weeding was conducted 11 times during the period of 10th October 2018 to 19th September 2019.

After every weeding, necessary irrigation was performed. In the absence of rainfall, soil moisture status was maintained by irrigation from planting to the establishment. Irrigation was discontinued 7-10 days before harvesting. After plantation of vetiver grass, the growth status was stopped and it became dry on 15th December 2018 due to cold weather conditions.

After one month later, revival progress was detected on the next observation on 16th January 2019. In research, we have measured my plant height in centimetre. We have also measured plant root length in centimetre. The number of panicle initiation and tillering numbers were counted. Panicle length was also expressed in centimetre. The dry weight of the total plant was measured carefully by the electric weight machine. Before harvesting the total data was collected 11 times in the research plot. Vetiver was harvested on 14th December 2019 by digging out the clumps along with its roots manually.

From the table 4 we come to know the evolution of vetiver grass growth. We can see at the very beginning when we collect data for the first-time plant height was found 12 cm and root length was 10 cm for the eight-growing tiller. It was cold winter days that we found comparatively less growth of the roots and shoots till March. We found plant height 12cm, 23cm, and 41cm when the root was 10cm, 12cm, 13.4 cm which was constantly low. With the temperature rise in April and May growth was recorded at its max. On the next data collection date, we found some extra growth of the tillers. For the month of May, June, July, August plant height was recorded 59cm, 90 cm, 117 cm, 132 cm, and root length was 14.2 cm,15 cm,15.6 cm, and 16 cm while tillering number reached 43 which was a very healthy growth.

For the last four months of the year it plants height increased to 154 cm, 184 cm, and 217 cm, and finally, 244 cm was found before harvesting. At this time root length was 18 cm and the tillering number reached its peak at 68. After calculation, this harvest was found enough effective for our purposes.

Table 4: Field data timeline collected from SAU campus

Date	Particulars	Plant Height (CM)	Root Length (CM)	Tillering No.
16.01.19	Data collection after 1st plantation	12	10	8
11.02.19	Data collection 26 days after plantation	23	12	9
28.03.19	Data collection 71 days after plantation	41	13.4	12
16.05.19	Data collection120 days after plantation	59	14.2	20
17.06.19	Data collection 152 days after plantation	90	15	29
21.07.19	Data collection186 days after plantation	117	15.6	38
22.08.19	Data collection 218 days after plantation	132	16	43
19.09.19	Data collection 246 days after plantation	154	16.7	52
14.10.19	Data collection 271 days after plantation	184	17.2	57
16.11.19	Data collection 303 days after plantation	217	17.6	63
13.12.19	Data collection 330 days after plantation	244	18	68

According to Collins Dictionary of Biology dry mass or dry weight is the mass or weight of biological material dried at 105 °C until no further water loss takes place. Because water content varies considerably between individuals. The evaluated variables were plant height (H); diameter of the stem (SD); leaf dry mass (LDM); stem dry mass (SDM); shoot dry mass (SHDM); principal root dry mass (PRDM); secondary root dry mass (SRDM); total root dry mass (TRDM); total dry mass (TDM); shoot height: diameter ratio (SHDR), shoot: root ratio (SRR) and quality index of Dickson (DQI) was measured. In the bellow table we highlighted only the result. Here we got shoot's weight 736kg, roots weight .288kg and full plant's weight 1.024kg.

Table 5: Vetiver grass dry weight collected from research area and SAU campus. The standard deviation and mean calculation are stated below

Descriptive Statistics					
Particulars	**Number**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Full Plant	4	1.024	1.140	1.081	0.049
Only Root	4	0.288	0.336	0.322	0.029
Shoot	4	0.736	0.804	0.766	0.024

Table 6: Vetiver grass green plant weight collected from research area and SAU campus. The standard deviation and mean calculation are stated below

Descriptive Statistics					
Particulars	**Number**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Full Plant	4	1.850	1.980	1.910	0.046
Only Root	4	0.418	0.472	0.451	0.020
Shoot	4	1.432	1.508	1.458	2.029

After getting the initial result we collect data from different places to compare the effectiveness of vetiver grass. We found vetiver grass growing quite gently in the natural environment without any management. If we notice the below table we can clearly understand the comparison. Here in North Pahartoli, Rangunia, and Ukhia, the growth of vetiver grass is far better than our research field. Plant height was measured 283cm, 298cm and 272cm respectively which are all better than our research field result. The same progress is found for the root length also and the root length was 23cm, 27cm and 20 cm respectively. And it is again not surprising that tillering number will also be better than our research field. And actually, it was found when we counted. The highest number of tillers was found in Rangunia and it was 75 when 73 was counted in North Pahartoli and 71 was found in Ukhia. So, we can assume that Vetiver grass is undoubtedly enough secure plant for our project for its extreme surviving capabilities.

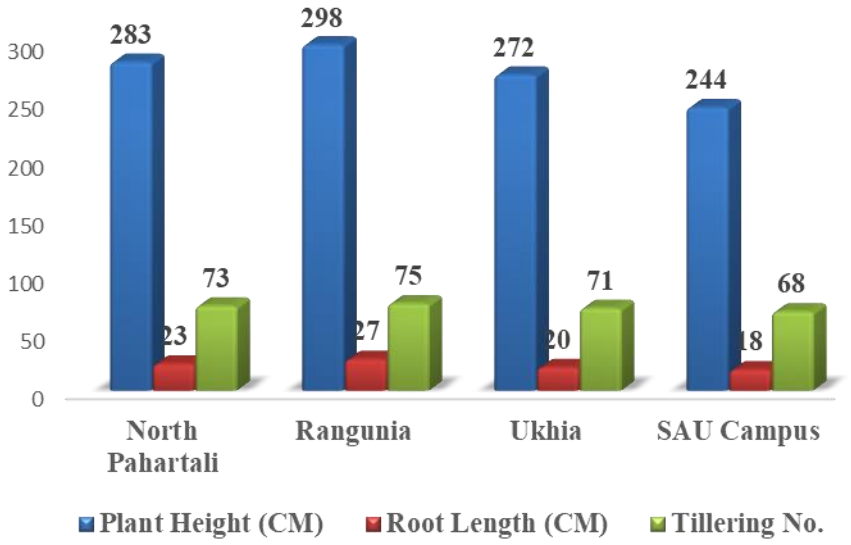

Figure 32: Sample data collected from research area and SAU campus

We evaluated another comparison showed in the table below were an average reflection of the vetiver plants its upholder. Here we can see the highest plant height and root length of vetiver grass was 298cm and 27cm when the lowest was 244cm and 18 cm. Thus, the mean plant height was found 274.25cm and root length was 22cm. The highest and lowest tillering number was 75 and 68 which means 71 or 72 tillers can be found on an average.

Table 7: The standard deviation and mean calculation are stated below

Descriptive Statistics					
Particulars	**Number**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Plant Height	4	244	298	274.25	22.809
Root Length	4	18	27	22.00	3.916
Tillering No.	4	68	75	71.75	2.986

Long *et al.,* 2001 found plant height 280cm on average in India which is very relatable to our plant height. Root length and tillering numbers are also almost same to our result.

Gill, 2005b showed in his research that plant height, root length and tillering numbers varies very slightly in the whole Asia. Except that he measured one of the tallest vetiver grass roots which was almost six feet. But the result we get is very satisfactory compare to his research also.

This study contains 140 respondent's responses in total which was accumulated from random people based on their profession and involvement with vetiver plantation. Among them, 120 respondents are classified under direct and indirect categories. Remainders are recognized as Govt. officers & NGO officers (8), Development agents & social worker (6), and village leader (6) accordingly. The study was conducted with five types of questionnaires for five groups of people. In terms of data analysis Govt. and NGO officers, DAs, SWs, and village leader's responses were quite fair enough but direct and indirect beneficiary respondents were far more effective in this regard. This study led us to focus strongly on direct and indirect beneficiary respondents. Other participants have faced with some open-ended questions which already been described in a different chapter.

CHAPTER 5

SUMMARY AND CONCLUSION

SUMMARY

The research was conducted at Dhaka, Chattogram and Cox's Bazar district, during the period from January 2019 to August 2020 to analyze the potential application of vetiver grass for sustainable environmental management in the hill tract region. Data were collected from 140 respondents from six different places in Chattogram & Cox's Bazar district. Among 140 respondents, 64 respondents the average age of 36-45 years. Here, 67% of respondents are male and 33% of respondents are female. Almost 47% of respondent's academic qualification is below secondary school certificate and 53% of them complete secondary schooling. 75 respondents of them having a family size between 5 to 6 members.

Indirect and direct respondent's general knowledge and any use of household activities on vetiver grass was 100%. 90% of direct respondents give their opinion about vetiver grass that can improve agricultural practice. It is found that about 111 respondents are given their opinion about hill slop protection and mudslide control happened through vetiver grass plantation. Plantation of vetiver grass can fight more effectively in the research area for disaster risk management 99 respondents believe it. 63% indirect respondents and 83% direct respondents gave a positive response about the slope protection technique in the Rohingya settlement area. All the direct respondents told the use of vetiver grass as animal feed. Whereas, 93% of direct respondents want to attend training from Govt. or other organization about vetiver grass practice. 109 respondents gave positive views about pest and disease management at the vetiver plantation site. 100% of direct respondents revealed that vetiver plantation can be a low-cost, eco-friendly, and sustainable technology for slope protection but only 3% of indirect respondents were not agreed with direct respondents. It is found that 74% of direct respondents gave an opinion about the activeness of NGOs and or government DAs/SWs in allocated areas not so up to mark. 100% indirect and 89% direct respondents told that

vetiver grass can be an income-generating opportunity for mass people. If govt. body or any private organization provide vetiver plantation-based system in this hill tract for mudslide protection 120 respondents willing to accept this opportunity. 43.3% of direct respondents were believed that vetiver grass cannot enough for socio-economic development in the hill tract region. 49% of direct respondents annually earned BDT 11000 to 20000 on the other hand 57% of indirect respondents earned the same as direct respondents earned. 115 respondents gave positive responses about improving their living conditions by using vetiver grass. We found that the majority of the respondents said awareness, sustainable policy, government, NGO support, and technical support are important key tactics for the successful adoption of vetiver grass in the hill tract region for overall social development.

CONCLUSION

The main purpose of this study was the potential application of vetiver grass for sustainable environmental management in the hill tract region of Bangladesh. The study established that the plantation of vetiver grass has a great impact on land protection in the hilly area. The potential application of vetiver grass is represented by the growth defined by its genetic potential and the ambient growth factors in the hill tract regions. Different practices are also identified besides vetiver applications for mudslide and soil erosion control to integrate them into environmental management. People's perceptions of adopting vetiver grass are brought under consideration through a specially designed questionnaire. This led us to make an authentic survey which helped many ways to understand their reaction to vetiver plantation. With the initial purposes, there are so many miscellaneous uses of vetiver grass which are also discussed to obtain social development in the hill tract region. Potential production of vetiver grass was determined by planting vetiver seedlings in the research field under perfect crop management with no limitation of water and nutrients and a weed, pathogen, and pest-free environment. Vetiver grass could play a vital role in the development of hilly area infrastructure and the national economy. Integrated management for vetiver cultivation, extension, and commercialization for increasing the living standard of the hilly people, especially poor women, by engaging themselves with vetiver related activities across the country. At the same time, proper research should be carried out to find effective methods of using vetiver for protecting the river embankments, canals, hill, and roadside, cropland from soil erosion.

RECOMMENDATION

- We need to educate local people about manifold use of the vetiver grass. Such as various handicraft materials like baskets, mats, hand bags, doll and ornaments etc.
- Marketing policy need to introduce for VG products.
- There should be Govt. / NGO or any other organization's involvement to teach them about these facts and give them training and provide them the necessary resources including technical and financial resources for macro-level usage of vetiver grass.
- The concerned bodies should give more attention to the advantages of vetiver grass for soil and water conservation practices.
- Potential opportunity like as Geo jute technique should be introducing among the people for controlling slope and mudslide.
- Similar studies may be undertaken in other parts of the country to verify the findings of the present study.

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APPENDICES

Appendix I - Interview Schedule for Indirect Beneficiary

(English version of the questionnaire of the study on):

"**Potential Application of Vetiver Grass for Sustainable Environmental Management in Hill Tracks Region of Bangladesh**"

Department of Agroforestry and Environmental Science
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka -1207

Date: …… **Interview No…**……

District: _____

Name	**:**	
Village	**:**	
Union	**:**	
Thana	**:**	
Mobile No	**:**	

Please answer the following question:

Socio-economic Characteristics of the respondents

Section 1: General Information

1. **Name of the Respondent**

   Gender: □ Male

   □Female

2. **Ages:**

   □ 18-25
   □ 26-35
   □ 36-45
   □ 46-60
   □ >60

3. **Educational qualification**

- Can't read and write
- Can sign only
- Read and write
- Primary
- Secondary
- More……

4. Marital status:

- Single
- Married
- Divorced
- Widowed

5. Family size:

- 1-2
- 3-4
- 5-6
- >6

a) Earning members

1	2	3	4	>4

6. Occupation:

- Farming
- Fishermen
- Businessmen
- Government employ
- Labourer
- Others……

7. In which income group do you locate yourself in the community?

- High income group
- Middle income group
- Low income group

8. Do you have **farm land**?

- Yes
- No

9. If yes, specify the **number and size** of the plot _____ & _____hectare

10. How did you **get** the land?

- from government
- from family
- leased
- purchased

To assess the potential application of vetiver plantation in hill tracts region:

1. Do you **know** vetiver grass?

   □ Yes □ No

2. According to your opinion, do you think vetiver grass have any use on **household**
   Activities?

   □ Yes □ No □ Not sure

   (a) If yes, **how does** it use in your household activities

   mostly?

   □ Thatch roof
   □ Fencing
   □ Green/ biomass fuel
   □ Livestock bedding material
   □ Wall hanging
   □ Low cost storage bin

   □ Others……

3. Have you used vetiver grass for the improvement of agricultural **practice**?

   □ Yes □ No □ Not sure

   (a) If yes, Mention practices;

   ……..

4. Does vetiver grass used as an **input** in the farm?

   □ Yes □ No □ Not sure

   (a) If yes, which is **mostly** used?

   □ Vetiver compost
   □ Mulching or moisture retention
   □ Bioremediation
   □ Field boundary
   □ Soil conservation
   □ Fodder
   □ Insect repellents

5. Does vetiver grass used as **handicraft**?

□ Yes □ No □ Not sure

(a) If yes, how is it **commonly** used?

□ Baskets
□ Mattress stuffing
□ Mats
□ Sachets
□ Lampshades
□ Hand bags
□ Dolls and ornaments

6. Does vetiver grass used for **structural strengthening** in hill tract region?

□ Yes □ No □ Not sure

(a) If yes, how is it **commonly** used for protection?

□ Earth embankment
□ Irrigation and Drainage channel
□ Hill slope protection
□ Mudslide control
□ Soil Conservation & protection
□ Gully rehabilitation and control
□ Pond, river and canal embankment
□ Hilly settlements
□ Others……

7. Does vetiver grass used for **industrial** commodities?

□ Yes □ No □ Not sure

(a) If yes, how is it **frequently** used?

□ Traditional herbal medicine
□ Vetiver grass root oil
□ Plywood and board
□ Pulp and paper
□ Ethanol
□ Cosmetics

8. Do you know **any technique** used in hill tract region for **mudslide control**?

□ Yes □ No □ Not sure

(a) If yes, which technique **mostly** applied?

□ Vetiver grass plantation
□ Retaining Wall
□ Installing pile

- Geo-jute installing
- Geo-jute with vigorous tree species
- Geo-jute with vetiver plantation
- Nets covering
- Brushwood check dams
- Gabion check dam
- Terrace
- Drainage for surface and sub-surface water control
- Tree and native vegetation
- Sandbags and straw wattles
- Plastic sheeting
- Others……

9. For what purpose do you use **vetiver grass on your plot**?

- Erosion/Runoff control
- Soil & Water Conservation
- Slop stabilization
- Land slide stabilization
- Terrace Formation
- Fodder / Grazing
- Border Demarcation
- Others……

10. From your observation, in which case vetiver plantations **fight more effectively** in hill tract region for disaster risk management?

- Flood control
- Cyclone
- Land stabilization
- Carbon sequestration
- Pollution control
- Wind break
- Natural barrier against fire event
- Others……

<u>To Identify the practices followed for mudslide and soil erosion control for environmental management:</u>

1. Does vetiver grass **contribute mudslide and soil erosion control** in hill tract region?

 Yes No Not sure

(a) If yes, how is it **frequently** practiced?

- □ As hedgerow
- □ As mixed with tree combination
- □ As strip plantation
- □ As contour and terrace plantation
- □ As cover crops
- □ As silvo pasture
- □ As mixed with tradition agroforestry system
- □ Along scattered sole slope planting
- □ Others……

2. Do you observe the specific practices of vetiver plantation with other **associated components**?

□ Yes □ No □ Not sure

(a) If yes, how is it **frequently practiced** with other components?

- □ As mango based
- □ As pine apple based
- □ As papaya based
- □ As banana Based
- □ As guava based
- □ As jujube based
- □ As taungya system
- □ As slash and burn
- □ As improved jhum based
- □ As mixed tree crop hedgerow/ horticulture garden
- □ Geo-jute accompanied with vetiver plantation
- □ As pasture system
- □ As edge of bench terrace
- □ As with plantation forest species
- □ As with sugarcane based
- □ As with tuber and rhizome based
- □ As with leafy and cucurbitaceous vegetable
- □ Others……
  …

3. Do you **notice** the practicing of slope protection technique **in rohingya settlement area** as an environmental management tools?

□ Yes □ No □ Not sure

(a) If yes, how is it **mostly** practiced in rohingya settlement area?

- As bare terrace
- As terrace planting
- Geo-jute technique
- As surface and sub-surface drainage
- As retaining wall
- As row planting with regular interval
- Along scattered sole slope planting
- Tree and native vegetation
- Sandbags and straw wattles
- Plastic sheeting
- Others……

4. Do you agree with the idea that **vetiver hedgerow** reduce soil erosion and runoff water increase soil fertility and moisture **than any other engineering methods**?
   - I strongly agree
   - I agree
   - I disagree
   - I strongly disagree

To evaluate people's perception on adoption of vetiver plantation in hill tracts region:

1. Do you know, **who introduced** vetiver grass to you?
   - NGOs Development Agents
   - Community leaders
   - Government Development Agents
   - From Print/electronic Media
   - Others……
2. For **how long** have peoples adopted **vetiver plantation** in Hill area?
   - 0-5 years
   - 6-10 years
   - 11-15 years
   - 16-20 years
   - More……
3. Do you know which **planting material** usually **choose** for vetiver plantation in hilly area?

   Yes No Not sure

   (a) If yes, which is **most commonly** used material?

- Cutting
- Culms
- Lateral budding
- Ratooning
- Tissue culture
- Others……

4. What **methods were used** in introducing vetiver grass for environmental management purpose?
   - Training programs
   - Workshops
   - Demonstration sites visit
   - Field visit
   - Others……
5. From your observation, which method is **most likely to occur** for the establishment of vetiver in hill tract regions for slope protection?
   - Natural system of vetiver establishment
   - Plantation system of vetiver establishment
6. In your own opinion, do you have the **plan to establish** and take care of vetiver Grass?

   Yes No
7. Do you think vetiver grass have **impact** on the **increase or decrease** of soil fertility?

   Yes No
8. Do you **notice** that the vetiver grass shows as a **weed or invasive characteristics**?

   Yes No
9. Do you know the processed **tender vetiver grass** shoot serves as nutritious animal **feed**?

   Yes No
10. Do you think vetiver grass **plantation slopes** are effective measures for mudslide control **than bare slope**?

    Yes No
11. If you get an opportunity to take **training and support services** from Govt. or other organizations on the vetiver grass practice, will you practice it in your

nearest area?

□ Yes □ No □ Not sure

12. Is there any special **requirement (input)** for practicing vetiver grass in hilly area?

□ Yes □ No □ Not sure

13. Have you **ever participated** on trining, workshop and demonstration of vetiver grass plantation before?

□ Yes □ No

14. Does vetiver grass **compete** with other crops for resources?

□ Yes □ No □ Not sure

15. Do you notice any **pest and diseases attacked** at vetiver plantation site?

□ Yes □ No

16. Does vetiver grass capable of **replenish after burning** hill vegetation for "slash and burn"?

□ Yes □ No

17. From your experience, does vetiver plantation program **more locally adopted** other than the government or private organization involvement/assistance?

□ Yes □ No

18. Do you agree that, Hill slope and mudslide protection through vetiver system can be a **cost effective** over other technique?

□ Yes □ No

19. Do you think that, vetiver plantation practice is **eco-friendly and climate smart** mitigation strategies for disaster risk management?

□ Yes □ No □ Not sure

20. Do you agree that vetiver grass **tolerate extreme environmental stress** (temperature, drought, flood, and other natural disaster) over other grass?

□ Yes □ No □ Not

sure

21. **Which grass** species shows **potential protection behaviour** in hill tract region?

- Napier
- Vetiver
- Bogamedula
- Others……..

22. In your opinion, how do you explain the **difference between** other system and vetiver grass system in **managing mudslide control**?

- No difference.
- VG is much better in controlling erosion than other system.
- Other system better control than Vetiver Grass System.
- VG makes the soil nearby more fertile
- VG system low cost technique than other system
- Others……

23. Which method do **you prefer**?

- VG
- Other methods
- Both

24. In your opinion, what will happen you think if you **stop using vetiver grass**?

- Soil loss increase
- Yield decrease
- Land degradation increase
- Runoff water increase
- Moisture decreases
- Mudslide increase
- Loss of income from VG
- No change

25. Is vetiver grass **easily accessible**?

- Yes
- No

26. If yes, **who supply** you the vetiver seedlings?

- Free from NGOs
- Purchase from NGOs
- Free from Government
- Purchase from Government
- Purchase from private
- Free from others /Specify……
- Purchase from others /Speciy……

27. Are you **still using** VG on your plot?

□ Yes □ No

28. If no, **why**?

……

29. How often the NGOs and or Government DAs/SWs **visit your site** for follow up and consult with you?
    - □ Very often
    - □ Often
    - □ Sometimes
    - □ Rarely

30. What's your opinion, **on which soil** vetiver grass establish more rapidly?
    - □ Sand
    - □ Silt
    - □ Clay
    - □ Diverse soil
    - □ Others…….

To judge the social development in hill tracts region by vetiver plantation

1. Do you think it can be an **income generating opportunity** for you and others too?

   □ Yes □ No □ Not sure

2. Do you think, if Govt. body or any private organization provide **vetiver plantation-based** system in this hill tract **for mudslide protection**, will you **support** it?

   □ Yes □ No □ Not sure

3. If vetiver grass is used to prepare as **low-cost eco-friendly products and services** will you use it for your **business purpose**?

   □ Yes □ No

4. If low cost eco-friendly **fuel shafts** are prepared by using vetiver grass, will you use it for your daily **household** fire activities for cooking?

   □ Yes □ No

5. Do you think vetiver grass plantation systems are **acceptable and eco-friendly** tools for **social development** in hill tract region?

□ Yes □ No □ Not sure

6. Do you think **besides hill protections** vetiver grass is **sufficient for socio economic development** in hill tract region?

□ Yes □ No □ Not sure

7. If government body or any private organization provides you vetiver grass-based **infrastructure setting** through you can **produce vetiver compost** will you take it to **use it?**

□ Yes □ No

8. How do you **generate income** from vetiver grass?
   - □ By making crafts from vetiver grass
   - □ By multiplying seedling for sale
   - □ By selling the grass for different users and for different purposes

9. How much money you generate from vetiver grass annually?

   ……Tk.

10. Is **the income** you generated **improved your living condition**?

□ Yes □ No

11. Will **you continue** using vetiver grass in **the future**?

□ Yes □ No

12. How do you express the **role of vetiver grass** planted on your farm land in soil erosion protection and **improve your leaving condition**?
    - □ Decisive
    - □ Important
    - □ Insignificant
    - □ Irrelevant

13. Do you suggest some **important key tactics** for successful adoption of vetiver grass in hill tract region for **overall social development**?
    - □ Awareness
    - □ Land ownership tenure
    - □ Genuine planting material
    - □ Intensive for planting
    - □ Govt. and NGOs. Support
    - □ Beneficiary parties
    - □ Extension and communication facilities
    - □ Sustainable policy

- Technical support
- Training on utilization of vetiver products
- Helps in life risk reduction

- More…….....

Specific Information

1. Do you know the **utilization** of vetiver grass?

   Yes No

2. If yes, **who introduced** vetiver grass for mudslide control purpose in your locality?

   - NGOs Development Agents
   - Community leaders
   - Government Development Agents
   - From Print/electronic Media
   - Specify the NGOs

3. **What methods** were used in introducing vetiver grass for environmental conservation purpose?

   - Training programs
   - Workshops
   - Demonstration sites visit
   - Field visit
   - Others /specify……

4. Have you **planted** vetiver grass on your plot?

   Yes No

5. If no, **why**?

   - I do not know the advantage of vetiver grass
   - Vetiver grass is not easily accessible
   - I do not have mudslide problem
   - Vetiver grass cannot protect mudslide control
   - I have better option than vetiver grass

6. Is there any disadvantage of planting vetiver grass?

   Yes No

   a) If yes, what?

   ……

   b) If no, how?

……

7. **Currently**, what type of mudslide control method are you using in your locality?

……..

……..

……..

Signature of the researcher Signature of the respondents

Thank you for your cooperation

Appendix VI: Morphological & Climatic Characteristics of experimental area

A. Morphological characteristics of the experimental field

Morphological Features	**Characteristics**		
	Dhaka	**Chattogram**	**Cox's Bazar**
Location	Agroforestry farm, SAU	Khulshi, Rangunia	Ukhia
AEZ	Madhupur track (28)	Chattogram Costal Plains (23)	Chattogram Costal Plains (23)
General Soil Type	Shallow red brown terrace soil	The soils are very strongly acidic, yellowish brown to reddish brown in color	Brown in color, usually loamy in texture and very strongly acidic
Land Type	Medium high land	Medium high land	Medium high land
Total Area	306.4 km²	5,283 km²	23.4 km²
Topography	Latitudes 23°42' and 23°54'N and longitudes 90°20' and 90°28'E	22° 14′ and 22° 24′ 30″ north latitude and between 91° 46′ and 91° 53′ east longitude	22° 23′ 30″ and 22° 27′ 30″ north latitude and between 91° 58′ and 92° 2' east longitude

Source: BBS 2013, Banglapedia

B. Climatic conditions of research area

Characteristic	**Value**		
	Dhaka	**Chattogram**	**Cox's Bazar**
Avg. Temperature	25.9 °C | 78.6 °F	25.7 °C | 78.2 °F	25.6 °C | 78.2 °F
Avg. Relative Humidity	74.0%	78.0%	78.0%
Avg. Rainfall	1854 mm	2794 mm	3770 mm

Annually average**
Source: Bangladesh Meteorological Department