2013 Engineers Without Borders Challenge

Building Sustainability Using Hemp & Bamboo Combined Plantations in Timor-Leste

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Executive Summary

Codo is a small rural village located in the Lautém district of Timor-Leste. This village has been identified by Engineers Without Borders (EWB) as a part of the 2013 EWB Challenge as an area which is in need of sustainable development. This area is largely characterised by rugged hills and mountains, with approximately 44% of the country having a slope of 40% incline. The combination of this rugged terrain and the annual monsoon season encourages soil erosion and landslip, subsequently damaging infrastructure, homes and agricultural crops. Infrastructure and construction is of extremely poor quality in Codo. Houses are traditionally made from rocks or bamboo, as the more permanent building materials, cement and steel, are too expensive for most locals. This paper addresses the issues surrounding infrastructure and construction in Codo and proposes a solution of establishing a combined plantation of industrial hemp (*Cannabis sativa* L.) and bamboo to develop a sustainable, affordable and environmentally friendly building material.

During the design process, several different solutions to improve infrastructure and construction have been considered as it is clear that there is a need for affordable, sustainable construction methods in this area. The proposed solution has been selected as it embraces the triple bottom line. It addresses the current need for a sustainable building material while having the potential to boost the economy of the local village, provides an environmental improvement to the local area and is likely to enhance the community by improving the quality of life and teaching important skills to locals that can be used throughout Timor-Leste for employment opportunities.

Our proposed solution consists of the propagation of linked bamboo and hemp plantations with the use of a specific plantation plan in the Codo area. The core aspect of this report is the use of the harvested raw materials to provide sustainable building practices. However, the benefits of these crops are numerous and although the scope of the project limits our potential solution, the intended benefits include:

- Strong bamboo housing framework from a sustainable source
- Hemp fibers from a sustainable source for use in insulation and Hempcrete which is similar to concrete and made from hemp and lime

- Reduction of the deforestation caused by illegal logging for cooking fires by providing an alternative cooking fuel
- The reduction of land degradation and land slips due to the strong root systems and additional land cover provided by the plantations
- Offering additional nutritional support to the diet of locals through the consumption of the hemp seeds which provide many health benefits

The plantation plan involves planting the bamboo, which has a very strong root system on higher sloping land to protect lower lying crops including any food that the locals may be growing and the hemp plantations. The clumping nature of the bamboo root system will easily stabilise the sloping land and divert the heavy runoff rainwater around the crops, protecting them. Bamboo is a common plant in Timor-Leste and will be able to be sourced locally. Hemp, unlike marijuana, is bred with very low tetrahydrocannabinol (THC) and cannot be used as a narcotic. The hemp plant has been grown by many civilizations throughout history for its benefits. It is local to the tropical climate and the seeds can be purchased relatively cheaply from a commercial hemp grower. Many countries including Australia, Canada and China currently grow hemp for its fibre. It is believed that the proposed solution will be culturally acceptable to the local community. However, there is little available research in this area.

The use of the raw materials, bamboo and hemp, in building applications will depend on the locals' ability to effectively harvest the crops. Our report details effective harvesting procedures to maximise yield and increase speed of growth. The cost of implementing this plan is minimal compared with the benefits it will provide. Although, as the local population have little wealth, they may need to rely upon a small government loan to purchase hemp seeds in the beginning. It is thought that as the new crops provide greater yields and as farming processes become more efficient, the farm area will be able to be greatly increased providing greater benefits. The project is intended to be self sufficient regarding cost.

Building with the materials consists of two components, the bamboo framework to form the walls and the Hempcrete as the wall filling. The strong bamboo structure will provide a solid

frame to which the Hempcrete can be fixed. The Hempcrete can be made locally from the harvested hemp and lime. If lime cannot be purchased due to availability or cost, the hemp fibers can be bundled to provide insulation properties. As the locals have been building with bamboo for generations, it is thought that minimal training in this area will be required. The construction process of Hempcrete and ways to implement it in building new dwellings is detailed in this report. The skills required to build with Hempcrete can be learned by anyone.

As a result of the many benefits, including the sustainable building aspect, the proposed solution will provide an affordable building material, provide local environmental benefits, enhance the local economy by providing a resource to sell or trade, provide employment opportunities and offer the opportunity for locals to learn new skills. The startup cost for this project is low and is possible to implement in a short period of time. It is for these reasons that this project will successfully enhance the sustainable development of the Codo area and be of great benefit to the local community.

Team Reflection

Roles:

Frank Morrissey – Chair

Damian Goldney – Dept. Chair

Keegan Hogarth – Treasurer

Bethany Kamitakahara – Secretary

Ben Hall – Editor / presentations

Michael Crame – Prototype manager

During the course of the 2013 EWB project, the group 4F came together to work very well as a team in creating a solution to the problems identified. Every member of the team has a good work ethic which was evident in meeting deadlines. Working as a team caused some scheduling issues as it was hard for the group to meet outside of allocated time due to other commitments. Nevertheless, time was always found to perform the tasks required due to a strong commitment to one another and the project. Well defined roles established early on set good structure for the group work environment. Everyone knew what their responsibility was at all times.

One challenge faced was experienced very early on in the project during the brainstorming process, the group identified three completely different possible design options when it was a requirement to select three design options in the same design category. This was quickly overcome and the group, after brainstorming some new ideas, was back in accordance with the requirements of the project.

The group was able to use the engineering rooms as a meeting place after the allocated time when extra time was required to discuss tasks to be completed. The group used an online drop box to share files. Although this did cause some formatting issues when sharing documents over different platforms. Overall, each member of the group was happy with the outcome of the research project.

Frank Morrissey

The challenges that were presented by the 2013 EWB project at first glanced seemed quite daunting, but with the help of an exemplary team I soon came to understand and embrace the objective of this subject. The project has enabled me to hone my current leadership skill set and develop in the area of report writing and referencing which are weaknesses of mine. We were all fortunate in that the group worked well together and there were no major personality clashes. The roles that we all accepted at the start of the semester remained unchanged and everyone has pulled together to meet the deadlines in a timely manner. This is not to say that it has always been plain sailing but with the groups strong commitment to the project the problems were overcome with relative ease. Once I understood that while this was an academic subject it could actually be realized the project has become more to me than just another subject. Because of the team I am working with, a subject, that I dreaded when I first saw the group work weighting, has become one of my more enjoyable subjects.

Damian Goldney

While undertaking the 2013 EWB project, I had the opportunity to sharpen many of my existing skills and in some cases, develop new skills. The project to date has been a rewarding experience providing an opportunity to learn about another part of the world and develop new friendships at university. One of the most difficult aspects of the project was the relatively short period in which we had to complete the tasks and arranging a suitable time for the group to meet due to each team member's work and university commitments. Overall, the group has worked very well together and demonstrated an underlying value of hard work and reliability. Every member of the group has made a solid contribution and attendance to weekly meetings has been exceptional. Each member has fulfilled their roles where applicable. My individual role, as mentioned above, is Deputy Chair. I have enjoyed this role within the group, offering guidance at team meetings and assisting the Chair. If I had to do the project over again, there isn't much I would change. I have been very happy with the progress of our group, in particular our ability to reach the required milestones in a timely manner. An area in which I could individually improve is in my note taking. I found that at some meetings, I didn't have the notes of some previous discussions that would have

helped us to progress. For me, the most rewarding part of the challenge has been learning how to develop a presentation as a group. I have presented individually many times before, but this has been my first experience of developing and presenting a report as a part of a group.

Keegan Hogarth

The 2013 engineering without borders (EWB) project has proven to be a challenging, yet rewarding real world topic alternative that has allowed myself and my group to look beyond the standard guidelines of a topic and create a final product that was completely our own. This project has given me the chance to increase my team working skills as well as meeting other first year students like myself. We have managed to work more and more effectively as a group as we near the conclusion of the project, as we have become more aware of what needs to be completed to reach the desired outcome.

The hierarchy of the group has remained the same throughout the project as the initial choices on the team roles where proven to be suited to each of the members strengths. All members of the group delivered their own ideas and opinions effectively to reach a satisfactory conclusion for everyone. Team attendance has been excellent as all members have been present for the majority of meetings and workshops. This has allowed us to reach the best possible solution and complete assessable tasks with minimal confusion within the group.

Personally I found that the EWB challenge has been a rewarding project that has improved many of skills that are essential for a future career in engineering. Researching is a huge part of the project and this topic has improved the efficiency and quality of my research. Oral presentations are also a major part of the project, which has allowed me to increase confidence in front of an audience. Finally, this project has been a beneficial group experience, which has allowed all members of our team to experience a functional workforce all working for the same outcome.

Bethany Kamitakahara

The Timor Leste challenge presented by Engineers Without Borders (EWB) has proven to be a rewarding and invaluable learning experience. At the beginning of the semester I was skeptical about the importance of the subject and doubted I'd learn anything of value. However, this opinion quickly changed as I began to appreciate the importance of developing skills in teamwork, researching and report writing. Not only that, but working on this real world humanitarian engineering problem has broadened my understanding of where the skills I develop during my degree can be applied in the future.

Over the course of the semester I was grouped with five other first year students and between us we are studying degrees ranging from biomedical engineering to computer science. The benefit of working within a diverse group is that everyone has different expertise, opinions and ideas to bring to the group. I was incredibly lucky with the team I was assigned. All team members attended the majority of our workshops and meetings, which in itself, made the project much more achievable as we didn't require extra meetings outside of the scheduled times. The online dropbox and emails were critical forms of communication and proved to be a great way of compiling the report and sharing ideas and articles. We quickly discovered each other's strengths, with some imperative leadership roles that proved to be an essential asset of the group. I think I worked well in the team, contributing my opinion as well as writing minutes and notes about each meeting. Not wanting to let the rest of the team down provided strong incentive to complete all assigned tasks. For the individual report my focus was on the cultivation, growth and processing of both hemp and bamboo. I believe I contributed quite significantly to the writing process of the report as I've written quite a few reports in the past and have had extensive experience referencing and researching. If I were to do the project again I would try to improve communication and leadership skills as I found these to be my weaknesses.

Although I believe we worked extremely well as a team, there were a few obstacles along the way. We had a tendency to think big and try to solve multiple problems instead of focusing solely on one solution. If we had more time I would definitely go back and be more specific in our solution as we simply didn't have the resources or time to go into the

required amount of depth to outline everything. Despite a few obstacles we came together well for the pitch and delivered a sound presentation, which boosted moral and confidence as a group. Overall I think the EWB challenge has been a great opportunity to improve teamwork, referencing and researching whilst learning about the issues associated with humanitarian engineering.

Ben Hall

The EWB Timor Leste challenge has been an excellent and an enjoyable learning experience. As a team I believe that our group worked really effectively together and that we were all dedicated to the EWB report. I also believe that we all tried our best and worked hard in trying to get the best result for the EWB report. As in all projects there are always obstacles, but because we were all dedicated, with strong leadership, we were able to hurdle them. My role in the group for the individual report was 'design options' for hemp/ bamboo reforestation and building. I believe that working as a team we were able to help one another's weaknesses and utilise each other's strengths. Each meeting we all assigned goals which we had to complete, which I believe made us an effective team. By being an effective team we all shared our opinions and we all had our fair share of research to do. If we had to do this project again I would probably make sure that our group could meet outside of class time more often, so we could get more done. The most positive part about doing this challenge was that we were able to help real people in a real situation, something which I have never done before. Reflecting on myself during the project, I demonstrated communication and the ability to research. Two weaknesses in my approach to the project would be time management and proof reading. During the EWB report, integrity was my underlying values. In conclusion I have found that this project led me to think about the lives of others in other countries.

Michael Crame

The EWB Timor-Leste Challenge has been a demanding and eye opening experience. It has been a tremendous opportunity and has made me eager to get involved in more projects like this in the future. Being part of a team improved my communicational skills, and it also taught me some new things. Group work was good; there were no major obstacles to

overcome or little nuisances getting in the way. The entire project has been done professionally and efficiently from day one. It feels good to have something that we have created that we can call our own, especially knowing that friendships were being built along the way.

If I were to do this project again I would suggest having more time spent for meetings. While we weren't short on time we could have benefited from an extra hour or so; we seemed to go overtime in every meeting. This project also helped me see what my own strengths and weaknesses were. I have learnt to effectively manage my time and improve my organisational skills. Overall I have really enjoyed the EWB Timor-Leste Challenge. It has been great to participate in a real humanitarian engineering project, helping real people, and I hope that there are more projects like this to be a part of.

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1 Introduction

While researching the Lautém district of Timor and in particular, the rural village of Codo, many different aspects of the daily lives of people living there have been considered. The design areas that the EWB challenge has been designed around have the potential to lift the local people out of poverty and generally improve their quality of life. It is clear that any proposed solution to the problems identified within Lautém must be affordable, practical and easily implemented into the local area. Of all the design areas, the most fundamental is Infrastructure and Construction. Considering the current dwellings that people of the Lautém district call home, it is apparent that something needs to be done to enhance their quality of accommodation. According to Maslow's Hierarchy of Needs, the most fundamental of all needs are physiological such as food and shelter (Lollar 1974, p.640).

As a result of this, Design Area 1 – Infrastructure and Construction, has been selected as the EWB project. The original twelve general possible solutions have narrowed down to three ideas within the same design area. The ideas consist of planting new crops to harvest the plants for use in many different areas but in particular, helping the locals design and use the raw material harvested to build stronger, safer and more comfortable accommodation. The reasoning behind the crops that have been selected is that there is great potential for multiple uses by the locals, most importantly the building material aspect. Some of the additional benefits of the crops that we have selected may improve the land erosion situation, be durable to heavy rainfall, enhance the diet of locals, provide fuel for cooking and boiling water and provide raw materials for sale or trade within Timor-Leste. The three final ideas that have been considered are:

1. Planting crops only of hemp.
2. Planting crops of bamboo and hemp together in a way to allow the crops to rely on one another using the strengths of each species' and attempting to eliminate their weaknesses arising from local environmental conditions.
3. Planting crops of just bamboo.

Hemp (*Cannabis sativa* L.), unlike marijuana, is bred to produce such low levels of tetrahydrocannabinol (THC), the narcotic that exists in the growth of marijuana, that it cannot be used as a narcotic (Shahzad 2011, p.973-986).

Through the use of a decision matrix, it appears that design option 2, planting a combination of bamboo and hemp crops, is going to be most beneficial to the local Lautém district as the crops should be more durable in the local environmental conditions and the resulting harvest will provide for additional uses.

The fundamental aspect of the project is to demonstrate in a simple but effective way how the combination of the two harvested plants could be used together to achieve a sound building method for the locals which would be practical to implement and of low cost. The resulting structures will have good insulation properties, be built from sustainable materials and most importantly of all, be able to be constructed by locals with little building knowledge.

1.1 Background

Codo is a small village in Timor-Leste in which, the local residents have little wealth. As a result of this, much of their infrastructure and construction is substandard. Suitable building materials are often too expensive for locals to purchase resulting in dwellings being constructed using only stones and bamboo.

The problems and needs of Codo that Engineers Without Boarders (EWB) identified in the project design brief for 2013 that this report addresses are:

- The current situation regarding the condition of dwellings
- The need for soil stabilisation to prevent further soil erosion and land slips particularly in the area surrounding the fresh water spring (EWB 2012)
- The need for flood mitigation to improve food security
- The global warming aspect caused by Carbon dioxide emissions.

The Timorese government can see a future in bamboo as a money making venture. To encourage enterprises to get involved, along with the United Nations Industrial

Development Organisation (UNIDO) and Volunteer Services Aboard (VSA), in 2003 they established the Bamboo Center. The Bamboo Center is a project to provide technology and hands-on training in the use of bamboo (one of Timor-Leste's most abundant agricultural resources) to create employment and generate income for rural people in Timor-Leste (VSA 2013).

1.1.1 Culture

Timor-Leste is a small country which has only been officially in existence for 11 years. It has a population of 1.2 million, and it is growing at a rate of 2.47% per annum. East Timor was occupied by Indonesia for 24 years, and over 183,000 people died from poor health or violence during that time. It gained independence in 1999 but was left with little infrastructure. It is now growing fast, building its economy mainly due to the exports of oil, gas and coffee.

Timor-Leste's economy is rapidly growing at over 10% annually. The export of oil and gas, which while bringing in income, has not created many jobs for local people. Since its independence, Timor-Leste has struggled to rebuild infrastructure and create job opportunities, leaving much of the population unemployed and in poverty. 49.9% of the population are under the national poverty line as of 2007, with over 30% without access to safe drinking water and over 40% without access to decent sanitation facilities.

1.1.2 Local Environment

Timor-Leste predominantly consists of mountainous terrain. Its highest point is Mount Ramelau at 3000m, and about 44% of the land is at a slope of approximately 40%. This speeds up the process of soil erosion when there are heavy rains (of which there are plenty in the wet season) (Engineers Without Borders Institute 2013). The terrain can be extremely rough, a motorcycle is often advised over an off road car.

The total area of East Timor is 14,874 square kilometres, 346.5 square kilometres of that is irrigated. A widely used slash and burn cultivation method has led to an increase in soil

erosion as there are less roots to hold the soil together. It has also contributed to deforestation, which leads to less water being used up by trees and plants. It is a vicious cycle, which leads to yet more soil erosion, reducing the amount of land available for crops.

1.1.3 Climate

1.1.3.1 Rainfall & Temperature

The average rainfall in Codo is 155.3mm per month (World Bank n.d.) but most of the rain falls from December through to March in the monsoon season (Figure 1). Due to the sloping nature of the land in Codo this causes flooding and soil erosion from the fast flowing water. United Nations Development Programme (UNDP) supported a scheme to assist villages with flooding. "The low cost solutions focus on bio-engineering; or planting various plants, such as bamboo, to hold the soil together" (UNDP n.d.). While the temperature does not vary much by Australian standards the humidity does change regularly.

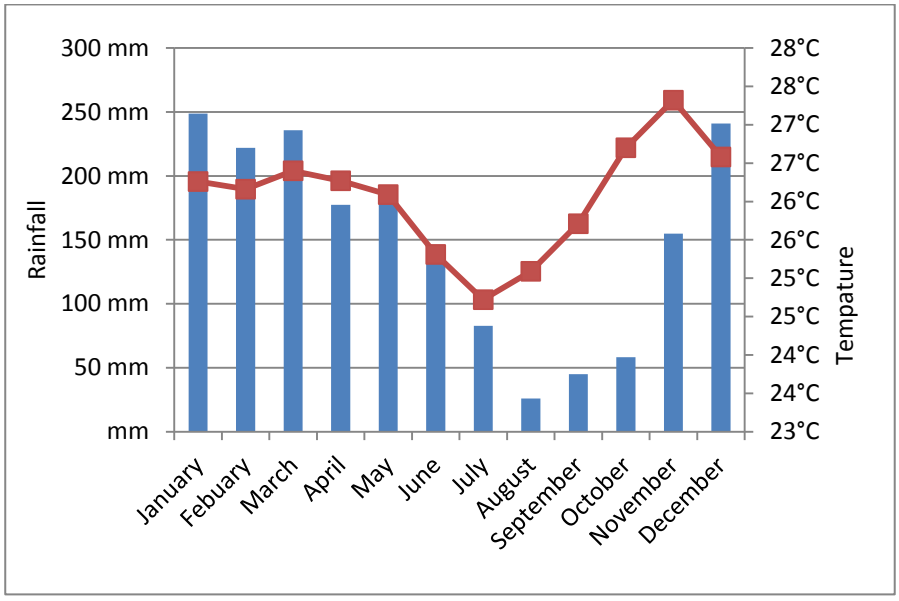

Figure 1. Average monthly temperature and rainfall (World Bank n.d.)

1.1.3.2 Monsoon Season

Between December and March, Codo experiences an annual monsoon season. This is when tropical storms sweep the area dropping large amounts of rainfall in a short space of time. This causes a high flow of water resulting in landslides that "are the most common natural

hazard in the country" (The Conversation 2011). The EWB brief highlighted the fear of the village regarding the current water supply located on higher land being of potential danger.

1.2 The Scope

The potential benefits of the proposed solution are numerous. This report limits the scope of the solution primarily to providing a sustainable building solution to the Codo village. This project focuses on growing, harvesting and processing hemp and bamboo while simultaneously stabilising land in an attempt to prevent further soil erosion and land slip. By limiting the scope of this project to farming these building materials, this allows the community of Codo to utilise them as they see socially and culturally appropriate. While the report is limited to these benefits, there is nothing stopping the people of Codo investigating and implementing additional uses of the materials harvested.

2 Design Options

This section of the report covers the three design options of:

- Bamboo reforestation
- Hemp plantation
- Hemp and bamboo linked plantations

Analyzing the potential design options has identified which solution will be more beneficial regarding construction and infrastructure. A data matrix for each option has been created to ensure the most beneficial solution to the people of Codo was selected as the subject of this report.

The intention of the data matrix is to provide a score creating transparency in selecting a design option to research. The data matrix is divided into several different sections all relevant to the implementation of the design options into the area. The sections are scored between 0.0 to 1.0 to provide a comprehensive picture of the advantages and disadvantages of each design option. This information has resulted in the design solution with the most significant benefits to the people of Codo being selected. The group voted on each of the components for each design option resulting in three final decision matrix totals.

Culture

Culture is a part of the data matrix, as it is important to know how the people of the Codo community will react to any one of the three ideas. The culture of locals should not be a deterrent to the implementation of any one of the three design options. The growth of hemp could be considered to be a concern of locals regarding culture, but properly informing them of the safety and nature of the crop should solve this potential concern. Culture is rated at 0.6.

Cost

It was decided that cost would also be in the data matrix as it is very important. Without money the project wouldn't be able to be implemented. Because the people of Codo have very little disposable income, it was decided that cost would be given a high score of 0.8 within the data matrix.

Environment

Environment has been included as it is an important component of the design options. The use of the strength of hemp and bamboo's root systems to stabilise sloping land may offer protection to the Codo people by preventing landslides. This is why the score given to the environment will be 0.8, the same as cost.

Achievability

Achievability is another section that has been included within the data matrix. Achievability is believed to be the most important aspect of the project. This is due to the fact that the main point of the assignment is to develop a feasible solution. Achievability has played an important role in choosing the final idea. In the data matrix, achievability scored 0.9.

Sustainability

Sustainability is an important aspect of the design solution as it will provide the potential for long term achievability of the implemented solution. Sustainability has scored 0.7.

Economic Development

Economic development is believed to be on par with sustainability in regards to importance. This is due to the importance of a strong economic growth of Codo to provide a sound future for the village. Economic development has scored 0.7.

Reliability

Reliability is the second most important section of the data matrix. Without reliability, the locals will lose trust in the project and no longer persist with the implementation. Reliability has a score of 0.8.

Longevity

Longevity, like other aspects of the selection criteria is an important part of the project. Longevity is related to sustainability. The goal of the project is to provide a long term solution making the longevity an important aspect. Longevity's score in the data matrix is 0.6.

Durability

As the conditions of the local climate can be damaging, the solution will need to be durable and be able to withstand all potential environmental conditions. The durability of the project is as important as the longevity. Durability has been given a score of 0.6.

2.1 Bamboo Reforestation

This design option consists of establishing bamboo crops to help stabilise sloping land, provide additional building materials in the form of structural bamboo supports and enhance the environment by absorbing some of the Carbon dioxide produced by the village.

Advantages

There are many advantages of growing bamboo, in the case of this report, the construction aspect of the harvested bamboo is considered. Throughout Asia, bamboo is used in construction and as scaffolding around high buildings. The most common species of bamboo found in Timor-Leste are *Dendrocalamus asper*, *Bambusa lako* and an unidentified species of the *Au-roma* (J.B.Friday 2007). Other advantages of bamboo are its strength to weight ratio and the fact that it grows quickly. Bamboo can also be used to stabilise land in situations similar to that of Codo. This design solution potentially could help the people of Codo by protecting them from landslides (Edward Carney 2012). In construction, bamboo can be used as ceiling and wall supports within a small dwelling.

Disadvantages

One disadvantage in using bamboo in building applications is its life expectancy. This is usually at best, up to five years. However, there are many non-chemical ways to preserve bamboo, such as keeping it in stagnated muddy water for several weeks. Also bamboo is prone to attack from insects and fungi. If bamboo stalks succumb to this, the people of Codo will not be able to use it as a building material. Another disadvantage of bamboo is that it is highly flammable and has been known to actually cause large forest fires. This can sometimes occur due to constant friction on the bamboo stalks in high winds. Another aspect of bamboo plantations as a design solution to consider is the duration in which it

could be established. Significant amounts of time and effort will be required to cultivate the bamboo and protect the crop until it is established (Bamboo as building material 2011).

DECISION MATRIX	culture	cost	environment	achievability	sustainability	Economical development	reliability	longevity	durability	total
Weighing	0.6	0.8	0.8	0.9	0.7	0.7	0.8	0.6	0.6	
bamboo	9	7	7	8	9	6	8	8	8	
Bamboo weighing	5.4	5.6	5.6	7.2	6.3	4.2	6.4	4.8	4.8	50.3

Table 1. Decision matrix – bamboo

Score

Bamboo reforestation as a design option receives a score of 9. As bamboo is already a big part of people's lives in Codo, it scored well in the area of culture and achievability. As the cost of implementing this plan is low, sustainability also scored well. The total score for the bamboo reforestation design option in the data matrix is 50.3 (Table 1).

2.2 Hemp Plantations

This design option consists of establishing hemp crops to be harvested for its many potential uses. The hemp fibre has good insulation properties, can be mixed with lime to make Hempcrete to be used in construction and the crop will also enhance the environment by absorbing some of the carbon dioxide produced by the village.

Advantages

Hemp will benefit the people of Codo in many ways. If the people of Codo implemented this design option, they could harvest the hemp to sell or trade, boosting the local economy. The harvested hemp crops can be used to make textiles, clothes, rope and an alternative cooking fuel just to name a few of the possibilities. The uses of Hemp are seemingly endless. Some additional benefits of hemp include the ability to be consumed as food, produce oil, insulate and purify water (The many uses of Hemp 2004). The hemp fibres can be mixed with lime to produce Hempcrete, which is a type of concrete made out of hemp and lime (Bob 2004).

Disadvantages

Even though hemp has a lot of advantages, the biggest disadvantage is the availability of hemp seeds. A reliable commercial supply of seeds needs to be obtained to make this a realistic plan. During the process of establishing the hemp crop, it will need monitoring and protection from Codo's heavy rainfall. The biggest concern in suggesting this proposal is the potential for rejection by the locals on cultural grounds. While they have nothing to fear as the proposal is completely legal, the reaction from the locals is unknown. It is possible that no association between the hemp plant and closely related Marijuana exists, therefore offer no reason for concern.

DECISION MATRIX	culture	cost	environment	achievability	sustainability	Economical development	reliability	longevity	durability	total
Weighing	0.6	0.8	0.8	0.9	0.7	0.7	0.8	0.6	0.6	
hemp	2	4	7	5	9	8	7	8	8	
Hemp weighing	1.2	3.2	5.6	4.5	6.3	5.6	5.6	4.8	4.8	41.6

Table 2. Decision matrix - hemp

Score

It is for this reason that in the area of culture, the design option of growing just hemp scored 2. The price of hemp seeds may require the community to obtain a small loan from the government resulting in cost scoring 4 in the data matrix. From an environmental perspective, as hemp can detoxify and regenerate the soil (Henry F 2013), it scored 7. Once the hemp has been harvested, its potential ranges from being sold to use in the production of goods for use or sale. For this reason, economical development scored 8. The design option concerned with the growth of hemp crops alone has achieved an overall score of 41.6 in the data matrix (Table 2).

2.3 Bamboo and Hemp

This design option involves the combination of growing both bamboo and hemp crops in unison for the benefits of each crop. The plan considers using the strong nature of the bamboo root systems to shield lower lying crops. While in a construction scenario, it is proposed that the strength to weight ratio of the bamboo makes it ideal for dwelling

framework and the hemp fiber used to make Hempcrete will provide an insulated home to shield the residents from the elements.

Advantages

The advantages of combining both hemp and bamboo plantations are numerous. The environment is improved as larger crops are will be established. The strong root systems provide stability to the unstable land at risk of land slip. The raw materials harvested can be used together for the purpose of building homes for residents. The alternative cooking fuel provided by the hemp elevates the deforestation in the area caused by illegal logging for timber to burn.

Disadvantages

The most significant disadvantage with a larger harvest area is the need for additional effort in field preparation and harvesting crops. As the yield will be higher from a larger crop, it is assumed that more people will become involved with the project as more people stand to benefit from the materials harvested.

DECISION MATRIX	culture	cost	environment	achievability	sustainability	Economical development	reliability	longevity	durability	total
Weighing	0.6	0.8	0.8	0.9	0.7	0.7	0.8	0.6	0.6	
hemp/bamboo	6	6	8	7	9	8	9	9	8	
Hemp/bamboo weighing	3.6	4.8	6.4	6.3	6.3	5.6	7.2	5.4	4.8	50.4

Table 3. Decision matrix – bamboo and hemp

Score

The data matrix of hemp and bamboo together received a total score of 50.4 (Table 3). This is the highest score received by all three possible design options. As the bamboo and hemp design option scored highest, it has been chosen as the design option that this report details.

3 Final Design Solution

Considering the scores produced by the data matrix (Table 4), this report will focus on growing hemp and bamboo together. The reason the design solution with the highest score has been selected is to provide the maximum benefit to the community of Codo.

By combining the advantages of each crop, it is believed that this will be a superior solution to the problems faced in Codo. While there are many benefits of the proposed solution, this report is intended to offer a solution in the design area of construction and infrastructure. The detailed description of the selected design option is presented in further detail in the next section of this report.

DECISION MATRIX	culture	cost	environment	achievability	sustainability	Economical development	reliability	longevity	durability	total
Weighing	0.6	0.8	0.8	0.9	0.7	0.7	0.8	0.6	0.6	
hemp	2	4	7	5	9	8	7	8	8	
Hemp weighing	1.2	3.2	5.6	4.5	6.3	5.6	5.6	4.8	4.8	41.6
hemp/bamboo	6	6	8	7	9	8	9	9	8	
Hemp/bamboo weighing	3.6	4.8	6.4	6.3	6.3	5.6	7.2	5.4	4.8	50.4
bamboo	9	7	7	8	9	6	8	8	8	
Bamboo weighing	5.4	5.6	5.6	7.2	6.3	4.2	6.4	4.8	4.8	50.3

Table 4. Final decision matrix

4 Detailed Description of Solution

4.1 Selection of Species

As a design solution of planting two separate crops has been chosen, identification of a suitable species for each crop is listed.

Hemp Species

Most industrial hemp farming around the world is of the hemp species *Cannabis sativa* L. This is by far the most common form of hemp bred with low THC levels for use in farming applications and as a result of this, is the subject of much of the scientific research into this crop. This species of hemp is suited to the climate found in Timor-Leste (Molyneux 2012, pp.823-840). The annual rainfall of the specific area where we are proposing to implement the crops is suitable for this species (Trainor 2010, p.24; Shahzad 2011, p.973-986). In countries that currently grow hemp for commercial use, the Governments have monitoring programs in place to ensure the crop's level of THC remains low. The Government in Timor-Leste may wish to implement such a program. They should be made aware of the potential that hemp crops may be grown in their area by providing them with a copy of this report.

Bamboo Species

Bamboo is a name used to describe a collection of species of giant grasses. It is estimated that there are between 1100 and 1500 different species (Van Der Lugt et al. 2006, p.648). Timor-Leste has many different varieties including the giant (*Dendrocalamus asper*) which has good building qualities. The aim of selecting the appropriate species will be based on three main factors:

- The speed of growth
- The stabilizing qualities of the root systems
- The strength of the bamboo itself

The strength of the bamboo will be fundamental as it is to be used in building applications (Figure 2). It is recommended that the species (*Dendrocalamus asper*) is used in Codo for its strength and suitability in construction applications.

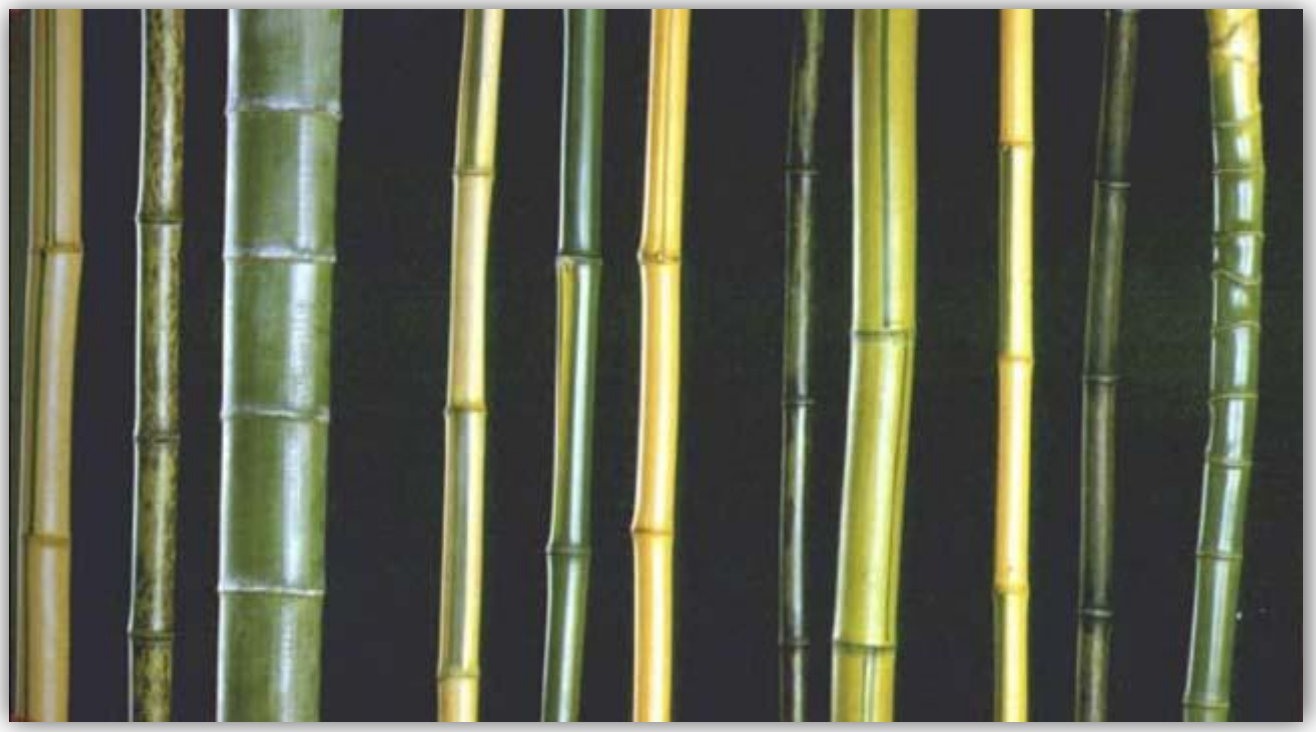

Figure 2. Various species bamboo (Van Der Lugt et al. 2006 p649)

4.3 Site Selection

The warm climate of Timor-Leste will provide an ideal growing climate for both of the crops selected. Hemp has been growing in similar climates for many years. Hemp a native plant to central Asia and it is known to have been grown there for more than 12,000 years (Shahzad 2011, p. 973). The Lautém district is the furthermost eastern part of Timor (Figure3).

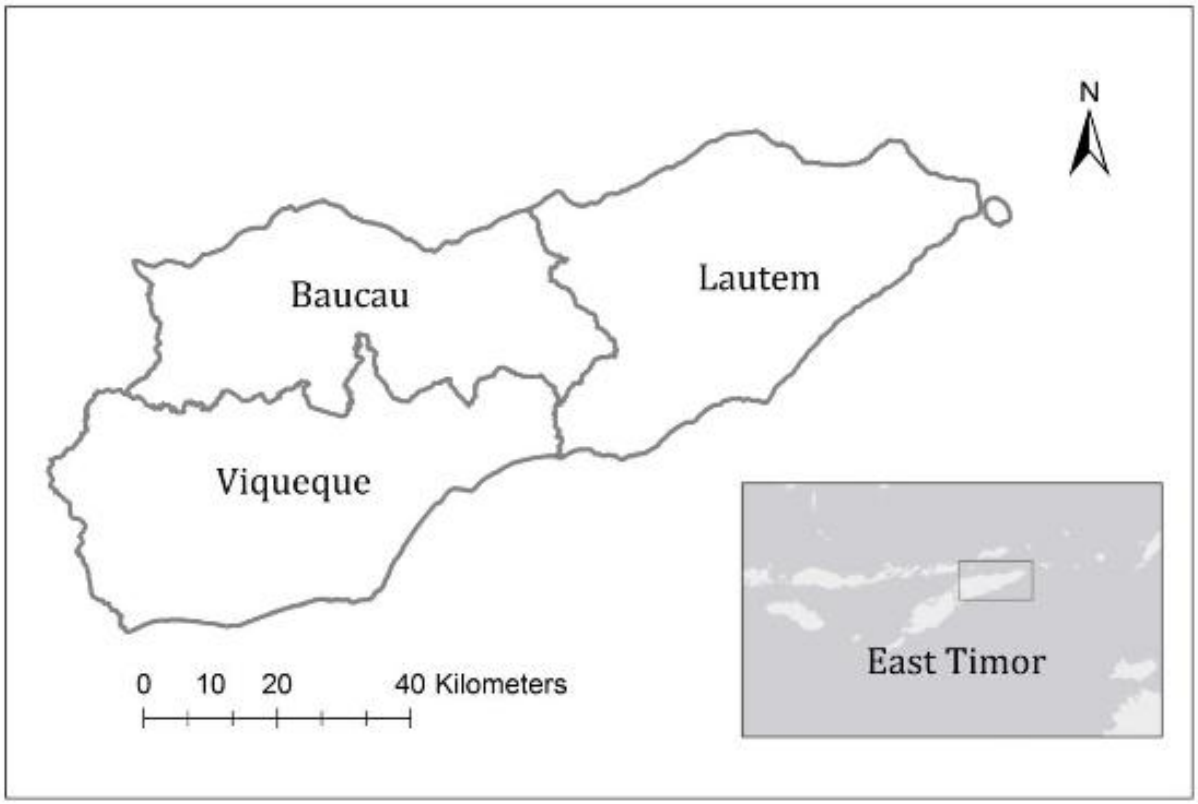

Figure 3. Map of the Timor-Leste area (Costa 2013, p.8)

Crucial to the specific site selection is the requirement to be close to the village and have a large enough area to grow a substantial crop. As transportation will be largely unavailable, a long distance back to the village with the harvested crop is undesirable. The advantage of the crops that have been chosen is that they will grow well on uneven ground. In fact, the hemp crop could potentially provide a higher yield if it is grown on hilly land rather than flat land (Science, 1891).The supply of local water may be required during the sowing process to ensure the seeds germinate and sprout. This may have to be brought in by bucket so being close to a spring or drinking water tap is relatively important. If sowed at the right time, this may not be a problem as the rainfall in this area is among the highest in Timor (Trainor 2010, p.24). Despite a dry period from August to October, the average rainfall of the Lautém district seems that it would be adequate to provide for the crops planted. Los Palos is a city in the Lautém district and is referenced on the rainfall graph (Figure 4).

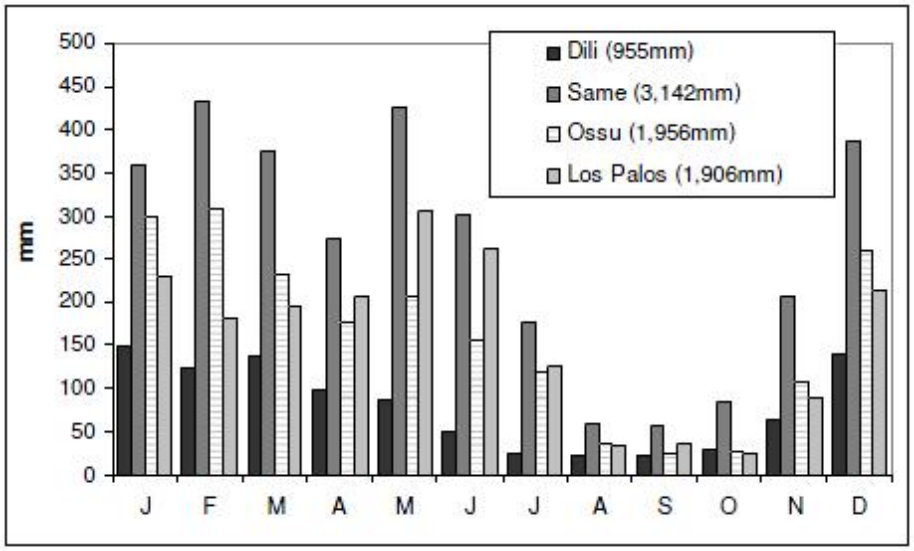

Figure 4. Timor-Leste rainfall 1959-1974 (Trainor 2010, p.24)

4.4 Propagation

It is believed that the bamboo will be able to be sourced locally. "However, the availability of bamboo seeds is limited due to a long flowering cycles (sic)" (Gulabrao et al. 2012, p.441). Bamboo can be propagated through clump divisions, however this method is not suitable for mass multiplication of bamboos. Culm cuttings however, are an effective solution for mass multiplication of bamboos (Banik 2008; Pattanaik 2004 cited in Gulabrao et al. 2012, p.441). This would involve finding a local bamboo plantation from which culm cuttings can be taken. This is a likely scenario as bamboo is found in large quantities around Timor-Leste. The hemp that is to be planted will need to be propagated from seed. The hemp seeds will be required to be purchased from an established industrial hemp organisation outside of Timor-Leste as it is unlikely that they will be found locally. There are many commercial hemp growers all over the world who would import hemp seeds to the area. The cultivation process can be labour intensive if machinery is unavailable. In the case of the Lautém village, much of the work will need to be done by hand and with the assistance of farm animals. Tasks involved in preparing the soil include ploughing, harrowing (breaking the soil further after ploughing), fertilization and then finally sowing (Figure 5).

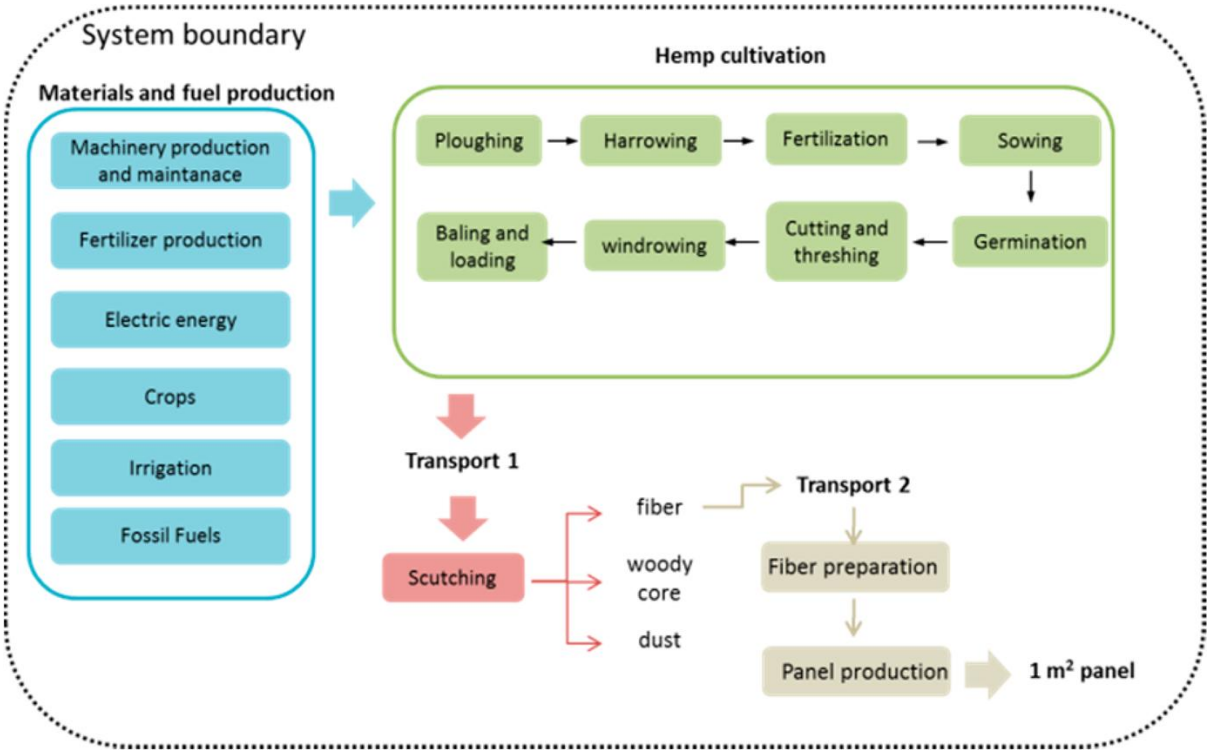

Figure 5. Flowchart of the production of a hemp-based insulation panel. (Zampori et al. 2013, p. 7415)

4.5 Plantation Plan

The aim of our project is to combine the use of two crops, bamboo and hemp to maximise crop yield and strengthen each crop. Land degradation is currently a problem that exists within Timor-Leste mainly due to soil erosion caused by wind and water. Free livestock grazing and slash and burn cultivation is also contributing to the problem. As the rural population increases, more people rely upon the natural forests for timber to fuel cooking fires which only exacerbates the issue (Costa 2013). By planting hemp crops in areas with high levels of soil erosion, the dense nature of the crop and the depth of the roots will reduce the effects of the wind and water on the land. Hemp roots that are not blocked by compacted layers of soil can reach up to 2m in depth (Amaducci et al. 2008, p.234). The ideal situation is to use the hemp crop, which is its own weed controller (Wilke 1996, p. 48) to reduce the effort required to control the weeds within the bamboo plantation. Furthermore, it may be possible to use the bamboo to shield the hemp crops. Even though we have found that hemp has a relatively strong, deep root system, a concern of planting a hemp crop on sloping land is that heavy rainfall may cause landslides or the excessive seasonal rain itself may destroy the crop. In some cases around the world, bamboo has been

used to stabilise sloping land. In the case of Apus bamboo (*Gigantochloa apus*) found in Indonesia, the root system is considered to be strong enough to add stability to sloping land and riverbank areas (Ma'ruf 2012, p.84). Considering the strength qualities of bamboo root systems, a bamboo crop planted on higher ground may provide shelter for a hemp crop planted in its lee. This may be used in an attempt to divert flood water around crops protecting the crop itself from potential harm and further reducing the soil erosion problems (Figure 6).

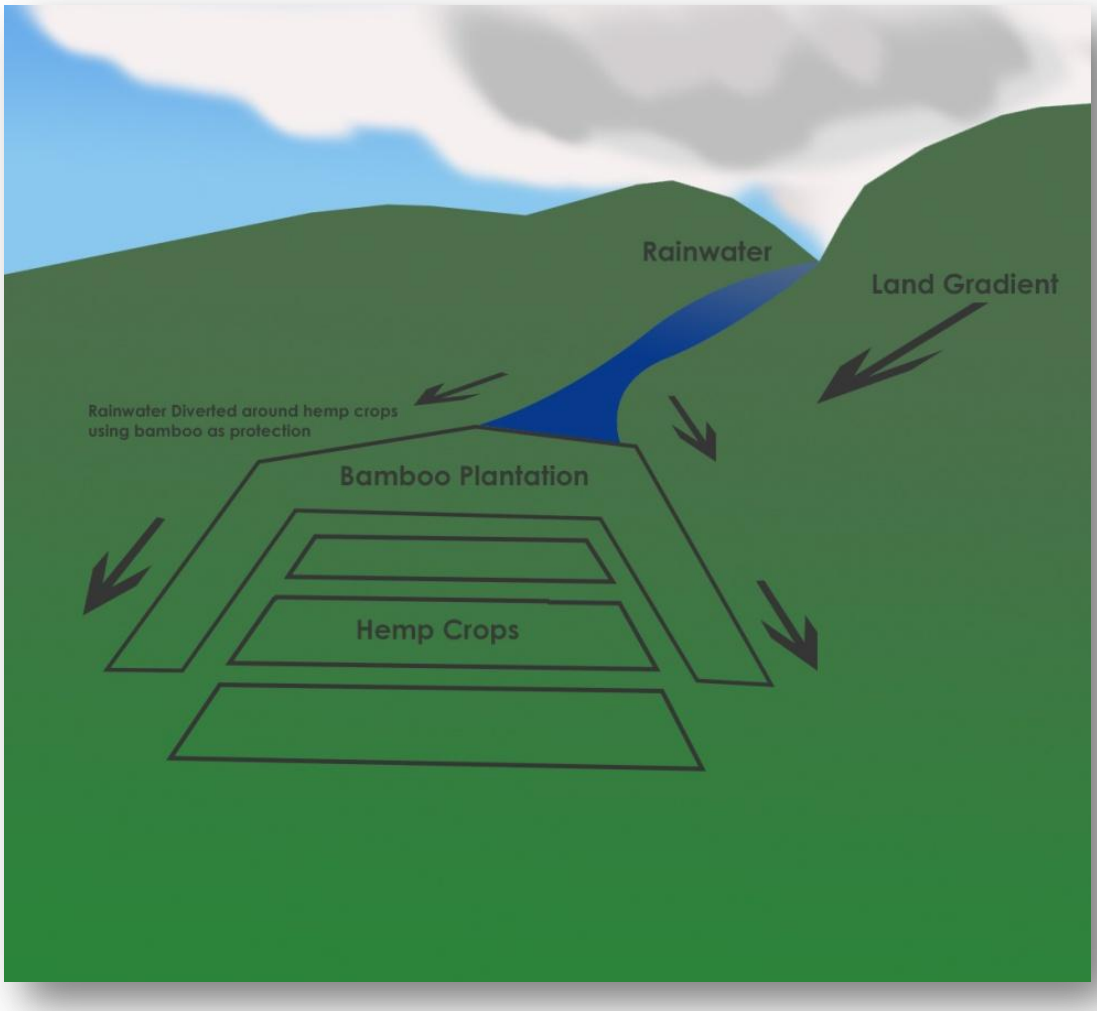

Figure 6. Plantation plan to protect hemp crops with bamboo plantations.

5 Hemp and its Benefits

5.1 What is Hemp?

Hemp (*Cannabis sativa* L.*)* is one of many strains of Cannabis. Unfortunately, a lot of controversy surrounds its use due to its association with its psychoactive counterpart, marijuana. The two plants are often confused due to various similarities in appearance and composition. However, unlike marijuana, hemp contains less than 1% of the psychoactive component Tetrahydrocannabinol (THC) and cannot be used recreationally. Hemp and marijuana also express very different mechanical properties. Despite hemp being entirely harmless when consumed, production and distribution of these products has been illegal in the past. However, extensive research and support of the immeasurable benefits of hemp have led to the alleviation of these restrictions in many countries around the world, including Timor-Leste. Although hemp's re-emergence and acceptance into modern day society will be a gradual process this will eventually be a booming industry. Therefore, Codo could benefit socially and economically through exports once the plantation is fully developed.

Figure 7. Layers of Hemp Stalk

Essentially there are three components of a hemp plant – the stalk, seeds and leaves. The hemp stalk has an outer layer of bark, which is made up of bast fibres, and can be used in textiles, weaving and composites; while the inner layer is called the woody core or 'hurds' and makes up about 70-80% of the stalk (Figure 7).

Primary bast fibres or the 'pith' is very similar to cotton. These fibres are long staple length fibres, which are approximately 20cm in length. Much like cotton, these fibres can be spun and woven into fabrics like clothes and linen (Figure 8). The second component of the hemp stalk is the core or the hurd and it closely resembles characteristics of

Figure 8. Spun fibres

wood. These fibres are found in the hollow hemp stalk of the hemp plant. It is twice as absorbent as wood, which allows the fibres to be made into concrete and plasters with the addition of a lime-based binder.

When growing hemp, many things must come into consideration. The climate is very important for the success of hemp crops. Hemp prefers a mild climate with 25-30 inches of rainfall per year as well as a humid environment. There must also be a considerable amount of free land to allow for the expanding and rising hemp forestation, as hemp plants can grow to heights of 4 meters and proliferate rapidly. The growing time varies between 70 and 90 days from seed to harvest. Not only is hemp a useful plant but also it's also easy to grow and requires very little maintenance. Hemp does not require any pesticides or weed control agents as weeds cannot grow within the hemp crop as it is simply too dense and suffocates the weeds.

5.2 History of Hemp

Hemp is one of the oldest fibers known to man. George Washington cultivated the use of hemp in the United States. Before The United States of America restricted the growth of hemp in 1937, it was used for a wide range of different things. The production of hemp was encouraged all over the world and the plant was used to its full extent. The restriction of the growth of hemp is controversial but many people believe that it was due to it providing competition to a new synthetic fibre at the time, nylon. As the Secretary of the Treasury at the time had invested heavily in nylon, laws were passed to restrict hemp growth.

Hemp has been used extensively and diversely throughout history. The first records of hemps use known to man date back to the Neolithic age in China. The Chinese used industrial hemp for all regions of life from shoes, clothes, rope and paper to a sustainable food source. Hemp was also used as a nutritional food source in medieval Italy and Germany. It was typically substituted as filling for pies, or used in soups.

Prior to 1950, hemp was used for ships sails and ropes. For sailors of that time, hemp was indispensable as it was the only source of fiber that could produce large sails and rope that

were strong enough to support a ship. As well as ship supplies, before 1883, 90% of the world's paper was manufactured from hemp.

During World War II the production of hemp was encouraged, as they would use it for cordage. It was chosen over other fibers as imports were of short supply. As soldiers needed shoes, clothes, and food, they needed to find their own source of a reliable fiber.

The official bill to outlaw hemp was brought to the House Ways and Means committee on April 14, 1937. This movement made it illegal to grow and use hemp. It was said that the drug, marijuana, produced hemp-induced violence and a dangerous drug. Despite hemp not containing THC, it was still considered an illegal plant. This brief description of the history of hemp, illustrates how critical this plant has been in the past and furthermore, how critical it could be in the future.

5.3 Potential Uses of Hemp

Hemp is considered one of the most useful natural fibres known to man. There are approximately 25,000 different consumer products that can be made from all parts of the hemp stalk. Hemp is commonly used to make clothing items, diapers, cosmetics, textiles, biofuels, food and building materials (Figure 9).

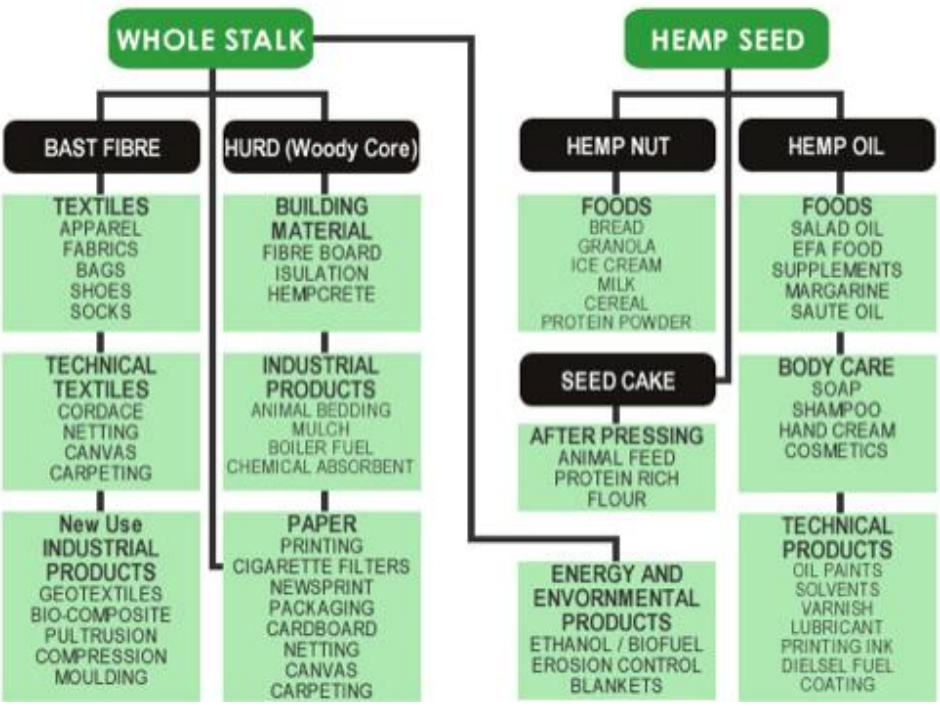

Figure 9. Possible uses of Hemp

Hemp seeds are another valued commodity for their application in food and cooking. Hemp seeds are composed of 30% oil, which can be extracted and made into hempseed oil. The seeds are also a nutritious source of food with a high content of protein. As hemp is an excellent source of protein, it has been made and marketed to body builders as protein powder with high lysine levels. Lysine is an essential amino acid for humans, which is commonly found in hemp.

Another useful application is the production of biofuels as it has the properties necessary to make petroleum. Hemp petroleum doesn't generate chemically toxic by-products; which will therefore reduce the amount of carbon dioxide (CO_2) emitted into the atmosphere. This product has the potential to reduce the effect of pollution on the environment and on global warming. Due to hemp's diversity, all aspects of the cultivated plant can be used and applied within the Codo community.

The woody core has a high tensile strength and has therefore been used to produce building materials, paper and mulch. More specifically, the woody core has been used to make concrete bricks. These blocks are as strong as normal concrete but much lighter, breathable

and environmentally friendly. To make this hemp-concrete, the hemp hurds must be combined with a lime-based binder and water. Although there are numerous applications of the hemp plant, the focus of this project will be on applying these qualities of the woody core into generating a sustainable building material in Codo.

5.4 Additional Uses of Bamboo

There's a wide range of uses for bamboo, making it one of the world's most useful plants. It is popular in Asia, even in large cities such as Hong Kong, for scaffolding, as well as being widely used as a domestic building material. It is chosen because of its strength, flexibility, low cost and the fact that it is extremely fast growing. Bamboo is also popular for making items for the home such as toys, furniture, flooring and ceilings, bicycle frames, musical instruments, trays and wicker baskets, kitchen utensils, pipes, paper and toilet tissue. It is difficult to estimate the number of uses for bamboo (although it is definitely in the hundreds), however they usually relate to the textiles and construction industries (Guadua Bamboo). As a result of its astounding versatility and resourcefulness, bamboo is now becoming popular worldwide in the creation and sale of ornaments and clothing. This makes bamboo a good commodity to have which will surely rise in value.

6 Cultivation

Industrial hemp (*Cannabis sativa L.*) and bamboo are both extremely robust and fast growing annual crops. Hemp can grow to heights in excess of 5m, while bamboo has been known to grow at a rate of 2 inches per hour if certain environmental conditions are met (Cole & Zurbo 2008; Bamboo KI 2011). Therefore, the conditions in which these crops are grown are essential towards maximising the quality and also yield of the product. Furthermore, crop production should be controlled by a specific series of processes (Figure 10).

Figure 10. Steps involved in cultivation

6.1 Soil Management & Seedbed Preparation

Hemp and bamboo need a well-made seedbed for a more successful germination and emergence. Industrial hemp can be grown on a wide variety of soil types, but it does best on loose, well-drained clay loam or silt loam soil with high fertility and organic matter (Cole & Zurbo 2008). It prefers a sufficiently deep, well-aerated soil with a slightly alkaline pH of 6.0-7.5 (Cole & Zurbo 2008). Similar to hemp, bamboo thrives in a sandy clay loam with a pH value of about 6.5-7.5 (Salam & Deka 2007). The bamboo plantation should also be on higher land and well drained, which is well suited to the project's plantation plan. To facilitate these conditions, it has been suggested that the land be ploughed and harrowed prior to sowing (Miller 2012; Zhijian et al. 2006). Conventionally, farming machinery such as a 4-furrow plough or a tractor would be used for these processes (Turunen & Van der Werf 2006). However due to cost restraints, gaining access to expensive machinery would be impractical in this situation. As an alternative, manual hoeing and weeding with a shovel, hoe and rake will suffice. This will be relatively inexpensive as these tools are used for current farming practices in Codo. Finally, the soil must be well supplied with nutrients like nitrogen, phosphorus, potassium and sulfur (Cole & Zurbo 2008).

6.2 Sowing

A large quantity of hemp seeds should be sown 4-5cm deep to achieve rapid germination and a dense crop (Cole & Zurbo 2008; Struik et al. 2000). This process should occur during spring or early summer (Cosentino et al. 2012). Self-thinning is an aspect of hemp cultivation that should be taken into consideration when sowing. Self-thinning is a density-induced phenomenon where larger plants suppress the growth of smaller plants, consequently causing mortality in the crop (Harper 1977 as cited by van der Werf et al. 1995). Van der Werf et al. (1995) found that plant height generally decreases with increasing row width and seeds should be sown evenly with 25cm between each row.

Unlike hemp, there are various ways that bamboo can propagate. These methods can be divided into sexual and asexual reproduction. Sexual reproduction occurs by sowing seed, while asexual is vegetative and can be via rhizomes, cuttings, macro-proliferation, layering and tissue culture (Salam & Deka 2007). The most feasible option in Codo will be to propagate from bamboo cuttings, as this is a fast, simple and economical method with a high survival rate of plants (Guadua Bamboo 2013). Pre-existing bamboo plants should be cut at ground level or just above the first node (Salam & Deka 2007). When planting these cuttings they should be 10-16cm deep and 40 to 50 cm apart. Bamboo is also native to Timor-Leste, which will make the cuttings easily accessible.

6.3 Harvesting

Flowering is frequently considered a reference point for harvesting as it influences the hemp yield in both quantity and quality (Amaducci et al. 2008). Industrial hemp is usually cut at the early flowering stage or just before the end of flowering, which is when the overall yield has reached its maximum (Cole & Zurbo 2008; Turunen & van der Werf 2006). The time of the harvest is significantly linked to environmental conditions (Struik et al. 2000).

Harvesting of mature bamboo culms occurs in the dry season in the third or fourth year after planting (Salam & Deka 2007). This is a labour intensive operation and sharp tools will be required to cut culms above the first node. It's estimated that 1500-2000 culms are

harvested per hectare after the 7th year of plantation (Salam & Deka 2007). Younger bamboo shoots can also be harvested as food during the rainy season. This may serve as an additional benefit of growing bamboo as these shoots appear and experience extensive growth during periods of high rainfall (Salam & Deka 2007). However, it's important not to harvest all of the shoots, as these will be required to grow into culms.

6.4 Processing of the Raw Materials

6.4.1 Retting & Decortication of Hemp

Immediately after mowing and harvesting, the hemp stems have a moisture content of 75-80% (Bruce et al. 2005). Retting is the decomposition and partial decay of stems, necessary to separate bast fibre from the woody core of the stem (Cole & Zurbo 2008; Bruce et al. 2005). As a result of retting, the outer part of the stem is sloughed. Cole and Zurbo (2008) have outlined three specific methods of retting including paddock retting, water retting and water-enzyme retting. Paddock retting is probably the most appropriate option in Codo as it's the most cost-effective option, requiring little manual labor. In this scenario, the crop is left lying outside for the fungal organisms to carry out the retting process (Cole & Zurbo 2008). Before and after this process, the harvested hemp should be stored outdoors in stacks, called "pyramids" and then stored in a dry, sheltered area (Figure 11; Turunen & van der Werf 2006). Finally, the harvested crop must be dried and decortication must occur where the outer layer of bark is removed from the inner fibers. This process of decortication can be done mechanically or manually. A 'hemp-brake' is a manually operated wooden press that breaks the stalks so that the inner woody core can be removed from the outer layer of fibres (Nelson 2000). This process is commonly used and may be applied in Codo.

Figure 11. Hemp in a pyramid stack

6.4.2 Chemically Treating Bamboo

Although bamboo doesn't require extensive processing like hemp, it is advised to chemically treat the cut culms for protection and preservation of the material. The freshly cut bamboo culms can be immersed into a solution of Borax of about 10% concentration for about 30 minutes (Salam & Deka 2007). This is an appropriate form of chemical treatment as it's relatively inexpensive and not toxic. Large culms should then be stacked horizontally, allowing air to circulate and aid the drying process.

7 Applications of Hemp & Bamboo

The potential applications of industrial hemp are extremely diverse. There are over 25,000 possible uses, from food and clothes to mulch and soap (Figure 12; Lawrence et al. 2012). The infrastructure and buildings in Codo are particularly underdeveloped. For this reason this project will be focused on developing a building material made from the harvested industrial hemp and bamboo.

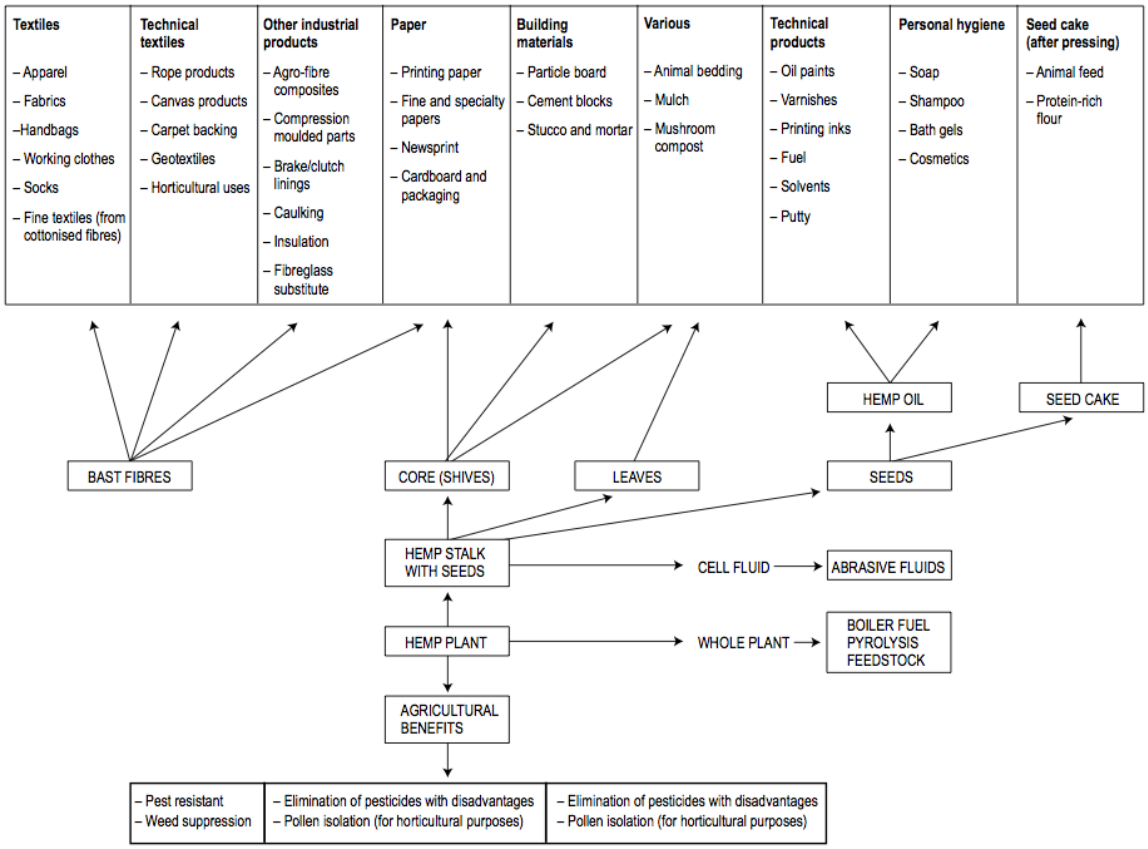

Figure 12. Potential markets and commercial applications of hemp (Cole & Zurbo 2008)

7.1 Hempcrete

7.1.1 What is Hempcrete?

Hempcrete, also known as hemp-lime and hemp concrete, is a light natural building material (Lawrence et al. 2012). A hemp stalk can be divided into bast fibres located in the bark, leaves, seeds and shives, which are found in the woody core of the stalk (Figure 13; Bruijn 2008). Based on the species cultivated, the hemp core is approximately 70-80% of the stalk

(Figure 14; Hempcrete Australia 2013). Historically, hemp shives were a by-product of the hemp fibre industry. It wasn't until the early 1990's that hemp shives were introduced in France to lighten concrete (Evrard 2006). The combination of hemp shives, a lime binder and water creates hempcrete (Lawrence et al. 2012).

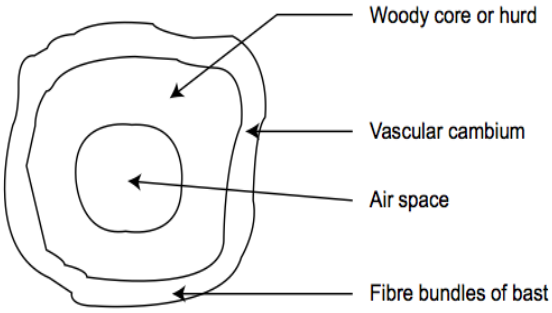

Figure 13. Transverse section of hemp stem

Figure 14. Chopped hemp shives from core

7.1.2 Production of Hempcrete

Hempcrete is composed of hemp shives, a lime-based binder and water (Lawrence et al. 2012). Lime is a material widely used in the building industry and is produced by heating calcium carbonate to 900°C (Bruijn 2008). Limestone, chalk, coral, rocks and shells contain calcium carbonate ($CaCO_3$) and can be used as a raw material for lime (Miller 2012). Heating calcium carbonate produces carbon dioxide and calcium oxide, also known as quicklime (Miller 2012). Quicklime is then combined with water to form hydrated lime (calcium hydroxide), which is the chemical used in hempcrete (Miller 2012). Conventionally, pan mixers and drum mixers are used to mix the hempcrete. Ideally a mixture will be homogenous in consistency so it is important to try and avoid formation of 'pellets' or 'balls' when mixing (Hempcrete Australia 2013).

7.1.3 Advantages and Disadvantages of Hempcrete

Hempcrete will be a locally available and incredibly versatile product to the community of Codo. The community will not only benefit from developing new skills in farming and building, but the final product will have countless social, environmental and economical advantages with very few disadvantages (Table 5).

Advantages	Disadvantages
- Low density material, therefore low thermal conductivity (Lawrence et al. 2012) - One ton of hemp absorbs 2 tons of carbon dioxide – good for the environment (Hempcrete Australia 2013) - Hempcrete allows transfer of moisture, which avoids build up of condensation - High tensile strength (Zhijian et al. 2012) - Well insulated - Lime in hempcrete makes it fire resistant - Pest, mold and mildew resistant - Sequesters large amounts of carbon dioxide during growth due to photosynthesis and therefore is beneficial to the environment - Hemp Shiv is a renewable source - Potentially no waste if the other components of the hemp stalk are commercialised - Inexpensive as the main component (hemp) will be locally grown in Codo - Locally grown and produced so this will minimise the need for long trips to other villages to buy building materials	- Variations in concrete quality - Lack of official mixing methods (Zhijian et al. 2006) - Unable to predict performance of concrete (Zhijian et al. 2006) - Manufacturing of lime binder releases carbon dioxide into the atmosphere – minimal in comparison to the amount of carbon dioxide absorbed by hemp (Hempcrete Australia 2013)

Table 5. Advantages & Disadvantages of Hemp and Hempcrete

7.1.4 Safety Precautions

As with any process involving potentially hazardous materials and chemicals, it is vital to take some safety precautions to prevent health problems (Hempcrete Australia 2013). When making hempcrete it is important to:

- Avoid contact with eyes
- Avoid breathing in dust
- Wear protective clothing where possible – gloves, eye protection

7.2 Manufacturing Plan

The aim of this project is to cultivate and develop sustainable building materials in the hope that they will not only improve the infrastructure and construction in Codo, but also the quality of life within the community. Bamboo is already an established and reliable building material in Codo. The introduction of hempcrete into Codo will drastically improve construction and infrastructure by providing a cheap cement-like support for bamboo structures. Although the scope of this project doesn't reach the specifications of exactly how to build homes, various potential applications and the recommended manufacturing plans will be outlined below. It has been estimated that the dimensions of a typical home in Codo could be 6m x 4m with a dividing wall to create two rooms (Figure 15).

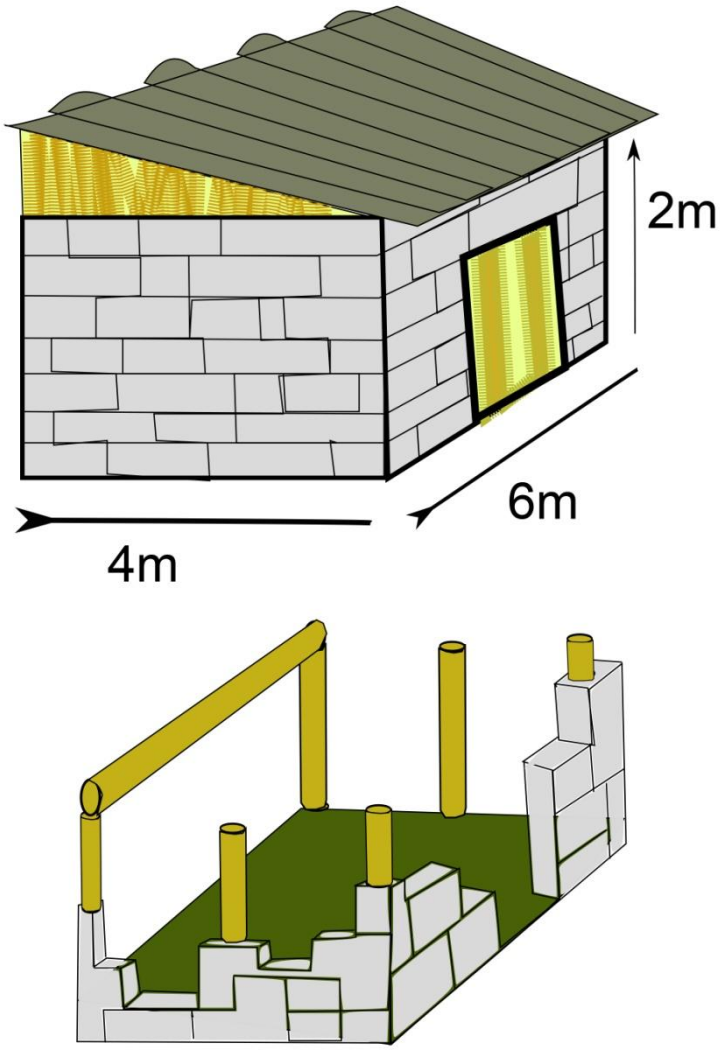

Figure 15. Proposed size of dwellings to be constructed in Codo

7.2.1 Bamboo Framework

Developing solid foundations of a building are essential to its endurance. Raising the earthen plinth as high as possible will potentially reduce damage caused by monsoon season. The stabilisation of the building can be achieved by setting a floor slab made of concrete and earthen plinth while simultaneously embedding the bamboo framework (Figure 16). These

Figure 16. Raised slab & bamboo framework

dimensions will have to be confirmed prior to construction. Previous bamboo structure homes have only had bamboo posts in corners of the structure, which has made the entire building unstable and weak (Arya 2010). Therefore bamboo posts will be positioned 1m apart to provide sufficient structural strength. All panels between bamboo posts will also have to be cross-braced with half-split bamboos and tied to parallel bamboo posts (Arya 2010). Cross bracing is an extremely important practice to increase stability (Figure 17).

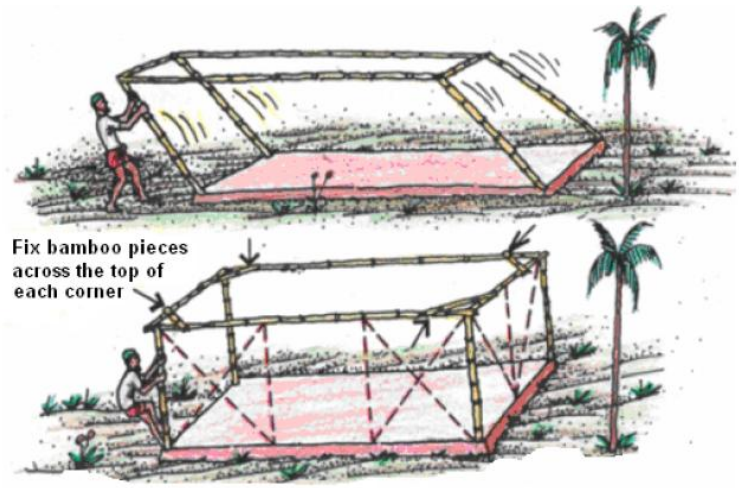

Figure 17. Cross bracing bamboo framework

7.2.2 Hempcrete

Hempcrete is cost effective, fast and light to work with. Because of the low water content of hempcrete it exerts very little hydrostatic force so the formwork could be made from tin or 6mm plywood. Once the basic structure of the house is complete, hempcrete should be applied to build the walls. As a safety feature, hempcrete thickness must be a minimum of 70mm between the bamboo frames to the outside of the wall. It must be noted that hempcrete is not a load-bearing material; therefore it should not be used to withstand roof-loads.

Hemp, lime and water are mixed 4:1:1 by volume but by weight, the mixture is closer to 2:3 for hemp to lime. It takes about 68 kg of lime and 45 kg of hemp to make one square meter of wall 300 mm thick, which equates to approximately $33.25 per square meter of wall or $1530 for the 6m x 4m house. The hemp hurd used in this house would weigh approximately 2070Kg, which is 36% of the expected yield for one hectare of the plantation.

8 Implementation Strategy

For this project to be successful it is essential to outline a comprehensible system of communication, education and training within the community. Communication between the EWB project team and the people of Codo may be challenging due to the language and educational barriers. The predominant language spoken in Codo is Fataluku; therefore the EWB team will require a translator throughout the entire process. The educational barrier also poses a challenge to the EWB team, as all training and education will need to be at a level that will be easily understood by the community. The most effective form of communication will be face-to-face consultation and training programs with EWB project members and experts in the fields of farming and construction. An initial information seminar and community consultation will identify people who are interested in being involved and establish their current set of skills. This consultation will then be followed by a set of two education and training programs overseen by the EWB team. This educational process will be supported by regular meetings, posters, and written guidelines.

8.1 Information Seminar

An initial information seminar with the community of Codo would be the first step towards implementing the proposed solution. This community meeting would aim to:

- Explain what industrial hemp is
- Explain the differences between Industrial hemp and marijuana
- Illustrate how the combined plantation of hemp and bamboo can benefit the community and minimise soil erosion
- Explain how hemp and bamboo will benefit the community socially, economically and environmentally
- Identify the benefits of Industrial hemp and bamboo in construction and in the community
- Describe the associated expenses and feasibility of the project
- Identify people within the community who are interested in contributing towards the project

- Identify people who already have skills in farming or construction
- Identify an area that the plantation could be established

During this meeting a survey would be taken to gain a greater understanding of who would be interested in contributing towards the project (Appendix 1). This will be useful towards determining how big the plantation can be and what skills need to be taught. Once everyone's roles in the project have been established; education and training programs can commence. This initial face-to-face consultation is not only important to teach the community about the project, but it's also vital towards forming good relationships with the people of Codo.

8.2 Education and Training Programs

Following the initial consultation, the community will have gained a basic understanding of industrial hemp and it's properties. Posters and brochures should be made available to the community to clarify any uncertainties regarding hemp. There are two education and training programs that should be implemented within the community. The first program will focus on developing skills in cultivating, harvesting and processing of hemp and bamboo. Farming is obviously a crucial component towards developing sustainable raw building materials. The second training program will focus on manufacturing and building skills.

<u>Program 1: Cultivation, Harvesting and Processing</u>

The conditions in which hemp and bamboo are grown are essential towards maximising the quality and yield of the product. This training program will be predominantly based on the detailed description of cultivation and harvesting in Section 7.0 of the report. The topics covered will include:

- Soil management and seedbed preparation
- Sowing
- Harvesting
- Processing of hemp

This is a hands-on training program and will be taught through face-to-face interaction and application at the plantation site with EWB team members and farming experts. This will continue to develop good interpersonal relationships and trust between the EWB team and the locals. This program should commence a few weeks prior to the farming season so that the EWB team can assist in the establishment of the plantation. It is vital for the EWB team members to explain everything in terms and concepts that can be easily understood by the workers. Several voluntary locals with previous experience in farming will be educated in greater depth. These individuals will play a crucial role in the sustainability and ongoing success of the plantation, as they will have greater responsibilities in overlooking and managing the farming process when the EWB team leaves. A written handbook will be provided to these individuals to refer back to. Leadership within the community will be important to continue education, training and improve the farming process.

Program 2: Manufacturing and Building

This program will build skills in applying the raw materials into infrastructure and construction. There are various approaches that could be taken when building with bamboo and hemp; however, this program will focus on constructing buildings with bamboo framework and hempcrete formwork. This will involve:

- Explaining the properties of hempcrete
- Outlining how hempcrete is made
- Explaining how bamboo framework can be made
- Explain how hempcrete can be used in housing
- Safety precautions when using hempcrete and bamboo
- Building a house

Similar to program 1, this will be a hands-on learning experience that will ultimately result in the construction of a house through the training and guidance of the EWB team and experts in the field of construction and infrastructure. During this education and training process it would also be beneficial to identify individuals with previous experiences in construction to suggest potential leadership roles. These leaders within the community will be supplied with a detailed guideline on construction of buildings using hempcrete and bamboo. Having

experts will be vital as although the EWB team will be crucial towards teaching the skills initially they will not always be around to provide support. Therefore, these leaders will provide continued learning and development within the community resulting in a more sustainable and successful outcome.

8.3 Community & Cultural Impact

Timorese people have a deep connection with the environment and cultural traditions. Due to various forms of conflict over the years, many monumental sights and objects of cultural significance have been destroyed. As a result there has been a significant push to promote nationalism and to expand cultural diversity. Timor-Leste is well placed to develop old and new cultural practices into creative industries that generate income, jobs and export earnings. We believe the impact of the combined hemp and bamboo plantation on the culture and the way of life of the Codo people will be relatively minimal. Farming is already a valued trade in the community. Therefore, the production of these raw materials will leave the community's cultural identity intact, while simultaneously improving the quality of life. Although we have suggested uses for these raw materials, hemp and bamboo are such diverse materials that the people of Codo can use them where they see fit and appropriate within their culture. For instance, these materials could be used to build schools or Child Friendly Spaces (CFS) to supply children with the tools for education and development. While undertaking this project, it is important to preserve traditional architectural heritage, particularly Uma Lulik – the sacred houses around which much community life revolves.

9 Cost

According to Robinson (1996) the yield of hurds is 2.5 tons/acre, which translates to approximately 5600 kg/hectare. With the bamboo frame and the hemp wall filling being grown locally the main expense would be the lime, which is available locally at a cost of $9.50 per 20kgs. It takes about 68 kg of lime and 45 kg of hemp to make one square meter of wall 300 mm thick, which equates to approximately $33.25 per square meter of wall or $1530 for the 6m x 4m house. The hemp hurd used in this house would weigh approximately 2070Kg, which is 36% of the expected yield for one hectare of the plantation.

10 Conclusion

The people of Codo, Timor-Leste have to endure substandard living conditions due to the availability and cost of building materials. Furthermore, the local environment is strained due to illegal logging which is reducing forest cover of the area. To make matters worse, as the area predominantly consists of sloping land and is subject to heavy rainfall, conditions are ideal for land slips and heavy soil erosion.

The proposed plan not only provides a sustainable building solution, but also offers a plan to protect crops from soil erosion, provide additional cooking fuel, supplement the nutritional intake of locals and protect land from land slips. The primary result of implementing this plan will be the availability of a sustainable building material and a method to use this material in construction of homes for locals. The subsequent results of this plan are an enhanced local economy due to a possibility of selling or trading harvested crops, new jobs created within the village, boosting the local community moral due to a common goal and protecting the local environment to allow for future growth and enjoyment of generations to come.

The farming are in Codo could progressively be increased with little cost. This is likely to occur once the locals become aware of the many benefits and efficient in the harvesting process. This is a solution that could be easily replicated in other parts of Timor-Leste. The setup and training of implementing this solution could be passed from village to village.

Implementation of this plan is simple and could be achieved in a short period of time. With a small loan from the government to purchase seeds, the people of Codo could use their existing knowledge of harvesting crops to begin immediately. Once implemented, this solution will be self funding ensuring the long term sustainability of the project. The numerous benefits to the environment and locals that this plan offers will make it a long term success. By providing locals a dwelling in which they feel safe and keeps them out of the elements, the quality of life of the Codo people will truly be improved.

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12 Appendices

Appendix 1

Codo Community Survey Name: Age:	
1. 1. Would you be interested in working at the hemp and bamboo plantation?	
2. What are your current responsibilities?	
3. Do you have skills in farming? If so, what do you farm?	
4. Do you have skills in building? If so, what materials do you usually use?	
5. Do you have skills in working with bamboo?	
6. Do you have any experience in leadership?	
7. If you have a good understanding of farming or construction would you be interested in a leadership role?	
8. Do you have any questions or concerns?	
9. What would you like to use the building materials for? Home, Child friendly Space (CFS), school etc.?	