Abaca in the Philippines

An overview of a potential important resource for the country

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Abstract

The purpose of this study is to do a broad map out of the abaca industry in the Philippines. Furthermore, the study aims to provide an overview of the abaca industry as a tool for finding ways to optimize the fiber production and to find suggestions on how to make a bigger share of the profit from the abaca products to stay by the farmers in the Philippines. The objectives are therefore also focused on describing the way the abaca plant is cultivated, harvested, processed, and further distributed from the farms. Also, the objectives are to describe the abaca supply and demand situation along with identifying challenges for abaca production.

Today the outmoded abaca production in the Philippines is experiencing a productivity loss which makes the farmers' incomes unnecessarily low. Important factors that, by this study, have been identified affecting the low productivity and profit are lack of proper farming management, distribution and unoptimized usage of the fibers. A big share of the abaca fibers produced is also being exported. This means that the raw fibers are being made into high-value products abroad and hence the profit to be made is dislocated further from the farmers with low means of improving their standard of living.

The study has been performed by doing a literature study complemented with interviews and visits to abaca farmers and other stakeholders within the abaca industry.
Introduction

As the environmental effects of climate change are getting worse the world takes more interest in finding sustainable solutions for the future. New types of materials that can limit or completely replace the need for fossil- and other nonrenewable sources is highly requested. The research on natural fibers as a renewable resource is therefore growing. One of these natural fibers is the fibers from the abaca plant. The abaca plant, native to the Philippines, is up and coming as a renewable replacement for synthetic fibers. Abaca is of great importance to the Philippines. However, it seems like the usage of the plant and its applications is not benefiting the Philippines in the highest possible extent. The productivity is far from reaching the demand which is a setback for attempts focused on increasing the income for farmers by, for example, using the crude fibers for a resource within high-value products.

Purpose and objectives

The purpose of this study is to, via literature studies and on-site visits, do a broad map out of the abaca industry in the Philippines. Furthermore, the study aims to provide an overview of the abaca industry as a tool for finding ways to optimize the fiber production and to find suggestions on how to make a bigger share of the profit from the abaca products to stay by the farmers in the Philippines. The objectives are therefore also focused on describing the way the abaca plant is cultivated, harvested, processed and further distributed from the farms. With this information, an additional objective is to identify challenges related to the abaca business.

The plant

Musa Textile Nee (see Figure 1), or Abaca, is a plant native to the Philippines. The plant is harvested for its fibers and is often called Manila Hemp. Despite the name, abaca is not a hemp plant but included in the Musacea (banana) family. In addition, the abaca is classified as a non-woody plant. The plant mostly consists of a cluster of leaves wrapped around each other which form a look-a-like tree trunk or a so called pseudostem (see Figure 2). Inside the leaf in the pseudostem is a soft non-fiber core. A pseudostem consists of around 12 to 25 leaves and the pseudostem has a diameter of 30-40 cm. The pseudostems color varies from greenish purple to blood red and has a glossy look. It consists mostly of water and sap, to about 90% and 2 to 5% constitute of fibers. When the leaves reach a certain maturity they unfold and form the characteristic green leaves, truncated and similar to the banana leaves. The glossy green oblat leaves have a size range from 1 to 2.5m lengthwise and a width of 20-30 cm. The plant develops both male and female flower. Though the male and female flowers develop during different time periods, making the abaca plants bound for cross-pollination. The female flower later develops the abaca fruit. The fruit is similar to its relative, the banana fruit, with green skin and white pulp inside. Indifference from the banana, the abaca fruit is inedible due to its high content of big black seeds. In one fruit the seed content varies from 30 to 160 seeds. However part of the flower is eatable, tho it is not widely done.
An abaca plant can, depending on the variety, live 25 years and become 7.5m long. However, the plant is often discarded earlier when cultivated due to its decrease in productivity as it gets older.¹

![Figure 1: Abaca plantation, Bicol, Philippines.](image1)

**The fiber**

The fiber classifies as a leaf fiber together with for example sisal and henequen ¹. Despite that classification, the fiber is not extracted from the actual green leaf but from the pseudostem. The abaca fibers are usually 3-15 mm long and have a diameter of 3-30 µm². In addition, it is claimed to be the strongest natural fiber ³. However, no measurements on the tensile strength of a single cell complemented with a declared methodology can be found. To be able to compare the fiber strength in a more exact and reliable way, testing of the tensile strength of single fiber cell has to be conducted.

Although there are reports of measuring the tensile strength of fiber bundles of abaca. The results confirm that the fiber has high strength. The tensile strength of the fiber bundles has a reported range from 600 to 900 MPa compared to the tensile strength of sisal fiber which is 511 to 635 MPa ⁴. Moreover, it is important to mention that the strength of the fibers varies with respect to the classification of the fibers ⁵.

The abaca fiber is also considered having good underwater durability. This is because it is resistant to salt water decomposition ². The fiber also has a high initial rate for moisture uptake, which also is considered an advantage for lignocellulosic fibers ⁶,³.

**Chemical content**

The abaca fiber is a lignocellulosic fiber which states that the chemical composition includes three major constituents, cellulose, hemicellulose and lignin. Compared to other nonwood fibers such as hemp, the lignin content in abaca fiber is relatively high with 13.2% of the total fiber ⁷. Regarding the other two main components, the fiber has a percentage of 63.2% of cellulose and 12 to 20% of hemicellulose ². In addition
to the mentioned above, the abaca fiber consists of wax and water-soluble materials such as pectin which is about 1% of the fiber.

**Current using areas**

Due to the high strength and underwater durability of the fiber, abaca is suitable for ropes and cordage, fishing lines and other types of marine tools. For those applications, the fiber has been an important export product since the 19th century. The cordage application area is 14% of the total fiber use. However, nowadays the main application of the fiber is specialty paper where around 80% of the fiber is used for. For this category, the fiber is used for example bank notes, filter paper and cigarette paper. In this area of application, the fiber strength is important for the uses as well. Other significant properties for the papermaking is the fineness and fiber length. With these properties, it is possible to produce a lightweight paper with high porosity.

The remaining 6% of the total fiber use is sorted as other applications. That is, for example, using abaca for producing textiles such as carpets and bags and in fiber craft such as baskets and wallets. For the handicraft making the outer layers of leaf sheet are suitable.

In 2019 abaca handicrafts such as weaving can be sold for around 3 USD/10m. A weave of around 60 cm width can be made in an extent of 30 meters a day which then would generate 10 USD a day. Also, one person can make about three handicraft baskets a day which are sold for about 3.5 USD per basket. This results in a daily income of 10 USD, for making the baskets. Handicrafts like these could then be exported to countries as for example Japan and sold to higher prices.

**Future using areas**

Also, with the growing concern about the environment considering global warming, pollution and deforestation, the abaca fibers have a good potential in some areas as a replacement for fossil fuel-based materials but also hardwood based materials. Especially within the area of biocomposites, the abaca got a void to fill. Today the demand for fiber reinforced composites is growing in all different sectors such as the automotive industry, packaging and construction industry. For industries trying to keep phase with the sustainable development mindset, the abaca could be one way for further dedication to that cause. Both within the packaging and automotive industry companies are focusing on redesigning products to lessen the usage of fossil fuel-based polymers by expanding the usage of natural fibers. For example, in Germany, there are manufacturers of vehicles working to make all parts of the vehicle biodegradable (except those who are recyclable such as the metalware and some plastics).

Considering plant fiber reinforced composites it is often a matrix made up of a thermoplastic (or thermosetting polymers) mixed with plant fibers to form a completely new material. Hence it is a hybrid material with components having
their own properties separately which then in a mixture combine those properties to form a new and unique material with special properties that the components could not produce apart from each other \(^2\). Usually, the fibers act as a skeleton carrying the load while the polymer matrix is fixing the polymers and hence keeps them in place. At the same time, it is also offering protection from surrounding factors such as humidity or rapid changes in temperature \(^2\). Common fibers that are used today as biofiber composites are jute, hemp, flax and banana \(^15\). The usage of abaca for fiber reinforced composites does not seem to be broadly used within the industry today.

Though there are modern examples where abaca is used for high-value products in composites. The German-American automotive company Daimler Chrysler has a patent for making an abaca reinforced polypropylene composite through a compression molding process \(^16\). This is a biocomposite intended for exterior protection for the underfloor in ordinary passenger vehicles \(^15\). Furthermore one can also find abaca in other parts of Daimler Chrysler produced cars. The company also uses an abaca reinforced polypropylene material for covering the spare wheel in some of their products \(^2\).

The dominant future area for abaca composites most certainly belongs to the automotive industry since this is the main area of growth for bio-based composites, uppermost, material for interior components are coveted \(^15\). Fiber reinforced biocomposites has a key role to play within the automotive industry since it offers material with lighter weight, high strength as well as material with a higher share of renewable materials \(^15\). Furthermore, the production of natural fiber is a process which requires low energy \(^14\). Incorporating lightweight material in composites such as natural fibers will also result in reducing carbon dioxide emissions by lowering the total weight of the final vehicle \(^15\).

Also, the polypropylene matrix reinforced with abaca is of great interest for the automobile industry due to several advantages such as the low cost, high tensile strength and high flexural strength. It has also good acoustic resistance along with a great resistance towards abrasion and UV-radiation \(^16\).

Using abaca for replacing glass fibers in components in automobile applications is also resulting in products with similar properties compared to the conventional glass fiber materials. Since the abaca fibers provide lighter weight, the end products possess similar specific tensile strength and specific elastic modulus as the conventional material \(^2\). It is known that the tensile strength of glass fibers is greater than abaca but comparing the specific modulus abaca is greater and also much cheaper and requires less energy input for production \(^2\). It is possible to reach an 80% reduction of energy use for the production of plant fiber-based fabrics compared to those based on E-glass fibers \(^13\). These are factors that contribute to making abaca an interesting subject for fiber reinforced biocomposites. Also, in 2007, the abaca was considered to be the first natural fiber to live up to the high standards for
automobile components placed on the exterior part of the vehicle like the Daimler Chrysler abaca reinforced PP-matrix. Making composites for exterior usage generates a high requirement for resistance to abrasion from the surrounding elements of nature.

However, there are challenges to address to further increase the usage and reliability of fiber reinforced biocomposites. One problem today is that the properties from one batch of fibers do not correspond to the exact same the next batch which makes the reliability of the final composite to decline considering the mechanical performance. Since the physical and chemical properties are depending on the type of abaca variety, weather conditions, way of harvesting and processing. There are a lot of parameters involved in changing the properties of the end product which makes the problem more complex.

**Cultivation**

The abaca plant usually grows in loamy soils with high sand content. The high sand content provides good drainage of the soil which makes the abaca thrive. It grows in areas with a temperature of around 20°C during the cold months and around 25°C or even warmer during the warm months. Also, the plant thrives in areas with high humidity with an RH of around 78-85% along with rainfall evenly distributed over the seasons. The abaca plant is rather sensitive to drought and only a few weeks of dried out soil will affect the final quality of the fiber. Along with the sensitivity for drought, the plant is also vulnerable when it comes to sun and wind in a fiber yielding point of view. It has been shown that reducing the full sunlight intensity with 50% gives a significantly higher fiber yield compared to plants grown in less shadow. Furthermore, the abaca has been reported to be easily damaged during windy conditions. This is a clear challenge since part of the country is covered by the typhoon belt. The typhoons tear the abaca leaves off and could even break the whole stems which of course affects the production of fibers by reducing the yield.

Considering that that abaca thrives in high humidity, is sensitive to sunlight radiation and wind it is crucial to include the abaca in an intercropping system and hence optimize the final fiber yield.

The intercropping shade trees provide farmers not only with means to protect the plants from sun and wind and hence enhance the fiber yields. The trees themselves also provide economic incomes. Today intercropped trees such as mango, coconut, coffee beans and many other fruit trees could be used. Along with those, the philFIDA (Philippine Fiber Industry Development Authority) also recommend trees such as cassava, peanut and turmeric. This means that there are several sorts of intercropping trees to choose from which also provides additional incomes as fiber yield optimizers and providers of fruits.
There has also been shown that incorporating legumes (nitrogen-fixing plants) in the intercropping system also enhances the fiber yield. Legume plants like Desmodium ovalifolium and Calopogonium mucunoides have been shown to increase the abaca pseudostem length and its circumference along with making the abaca leaves bigger and hence increasing the amount of extractable fibers\(^2^3\). Crops like these also seem to have an important role to generate a suitable soil structure, protect the soil from severe rainfall, fluctuations in temperature and providing organic molecules rich of nitrogen for fertilization \(^2^3\). Therefore an important aspect of optimizing the fiber yield is the setup of the abaca plantation with integrated crops through intercropping to increase productivity and farmer’s income.

The plant is cultivated by four principal ways which includes:

- Corms, also called seespieces
- Suckers
- Tissue culture
- Seeds

The way of establishing the abaca in the field through tissue culture takes three to four months. This counting from planting the plantlets within the nursery to transposition to the plantation site in the fields. The clear advantage of using tissue culture is that it is possible to produce plantlets free from diseases \(^2^0\). Before the tissue cultured plantlets are reaching the fields they go through a process of acclimatization \(^2^4\). This hardening process takes place in a cheap and primitive nursery often called a “Collapsible satellite nursery” in cubed shape space constructed with bamboo sticks as a frame and layers of fishing nets as roof and walls \(^2^4\). PhilFIDA has provided the following guidelines for nursing the tissue cultures:

“The tissue cultured plantlets are planted in plastic bags in a media of sand and regular garden soil (1:1 proportion) which preferably has been sterilized by sun drying to avoid fungal infections” \(^2^4\). PhilFIDA recommends the plants to be irrigated daily and also sprayed with insecticide monthly before establishing in the field after 3 to 4 months.

Though the more traditional way of propagation is done from seeds. To grow from seeds results in advantages since it does not require high costs and hence is affordable for farmers. Though at the same time a healthy and good quality “parent plant” will not assure a corresponding seedling quality \(^1^7\). It is a fairly easy methodology and one of the most important factors is that seeds possess a greater resistance to diseases and drought \(^2^5\). The seeds are derived from plants that are confirmed disease-free either by diagnostic tests or just by visual inspection \(^2^5\). The seeds take about one week to germinate and further three weeks before transposition to a nursery. The plants go through a hardening process for two months and by the time they developed five leaves they are ready for plantation in the field \(^2^5\).
Moreover, the abaca could be propagated through sucklings in two ways. The first way includes the sucklings being cut off the root from the parent plant without damaging the original plant. These sucklings will result in an identical version of the parent plant and hence a good quality suckling can be assured by proceeding from a reliable, productive and high-quality parent plant\textsuperscript{17}. The parent plant could produce around 10-15 sucklings ready for replantation\textsuperscript{11} (see Figure 3). Compared to seedlings the plantlets derived from sucklings will mature more quickly but at the same time, they have to establish their own root system which means it is not the fastest way of obtaining plants ready for harvesting\textsuperscript{17}. In addition, there is a faster method to obtain sucklings that mature faster. This method is more costly but will at the same time result in less time from plantation to harvesting. This way of using suckling will destroy the parent plant since the rootstock is being dug up and divided into pieces containing suckers-shoots which are then planted. An advantage of this method is that the rootstock pieces already got a developed root system though it will eliminate the parent plant\textsuperscript{17}.

![Figure 3: A suckling along the parent plant.](image)

Another thing to consider before planting the abaca is which type of abaca to cultivate since there are several sorts of them optimized for different regions and results in different fiber yields. For example, the high yielding sort best suitable for the Bicol region is “Musa Tex 51” with a yield of 2 085 kg/ hectare and year compared to “Linawaan” best suitable for Visayas region with a yield of 1320 kg/hectare and year\textsuperscript{18}. For a detailed overview of the different sorts of abaca, see Appendix, Table 3.

**Harvesting and Processing**

The abaca is harvested by hand continually approximately every five months after an initial growth during one to two years. The plant is exchanged after around ten years
and another initial growth period is introduced. It is important for harvesting to take place at the right time to get the desired properties of the fibers. The time of harvesting is also correlated to the yield of fibers. The harvesting takes place before the abaca blossom is matured when the three flag leaves appear which are the smallest leaves pointing straight up compared to the larger ones that form a larger angle with the pseudostem. The stem should not be harvested if the plant is over matured since this will result in fibers with a more brown color. Also, stems which are not yet matured will result in fibers that are not sufficiently developed and got low strength. The actual harvesting and extraction of fibers can be summarized by four steps which include:

- Tuxying
- Stripping
- Drying
- (Baling)

**Tuxying**
The tuxying takes place when the appearing green leaves of the abaca have been cut off the pseudostem. The tuxying includes separating the leaf sheets building up the pseudostem and then separating the outer leaf sheath layer from the inner leaf sheath layer. The separated outer part of the leaf sheath is called tuxies. One leaf sheath generates around two to four tuxies. The section of each leaf sheath making up the tuxy contains the primary fibers while the inner part of each separated leaf sheath is home to the secondary fibers. The different levels of leaf sheaths belong to different grades of quality through a grading system. Though the grading system contains more factors to consider. The different levels of sheaths generate fibers with different color, strength and also texture. Those layers then generate fractions of fibers suitable for different forms of industrial applications. The outermost sheaths are darker in color and make up 5% of the harvested petiole while the inner layers possess an ivory color and are also stronger than the outer ones.

**Stripping by hand**
The stripping is either done by hand or by machine to different extents. The manual stripping is a primitive way of fiber extraction which gives low investment costs in comparison with more improved methods. The by hand stripping includes the tuxies being placed between a blade and a block of weight which presses the tuxie against the cutting-edge of the knife. Sometimes the knife could be serrated to facilitate the extraction of fiber bundles which usually is a very physically demanding labor. The tuxie is then manually pulled perpendicular to the cutting-edge which leads to an extraction of the tuxie fiber bundles of abaca. Since the thickness of the obtained tuxies varies, the width between the blade and the block can be adjusted by a pedal hence pressure against the cutting-edge is therefore adjusted to fit each tuxie.
The whole tuxie is not stripped in one pull since the stripping operator needs one end of the tuxy to grab as he or she pulls it over the knife and therefore needs to do a regrip to strip the other end of the tuxie as well\textsuperscript{5}. Furthermore, the reason for doing the tuxying to extract the outer part of each leaf sheath is to make the pulling of the tuxie along the cutting-edge of the knife easier and hence ease the burden of stripping\textsuperscript{20}. The primitive methodology is obviously a disadvantage for the farmer productivity but it is an easier way to get in business with since it requires low investment costs. Regarding the hand stripping method, one trunk of abaca will give as much as 0.5 kg of extracted fibers\textsuperscript{11}.

\textbf{Figure 4:} The setup of a traditional hand stripper mainly made of bamboo.

\textbf{Figure 5:} A neat, modernized, stripping tool with serrated blades.

Also, there are farmers that strips the tuxies without a knife at all (see Figure 6). Instead, farmers are using their hands to extract bundles of fibers\textsuperscript{12}. To thinner the tuxies before striping the vascular and parenchyma cells are being scraped off against a tree. This is a very slow and low yielding way of production compared with the previous method. Since tearing tuxies into fiber bundles by using fingers is not a very precise and consistent method it results in fiber bundles of varying thickness and purity and hence a lower grade.
Figure 6: Extraction of fiber bundles by using hand ends up in bundles with a high varying width and a higher risk of contamination.

**Stripping with spindles**
The improved way of stripping is a semi-automatic stripping process where an electrically driven spindle pulls the tuxie over the cutting edge. This method is a more common one in Central America in relation to the Philippines. The principles are the same as manual stripping. There is a knife with a corresponding stripping block which provides an adjustable pressure with the help of a pedal. As for hand stripping the tuxies are being placed between the blade and block and the end of the tuxies is then wired around a rotating spindle that pulls the tuxies over the blade. This method also needs a regrip to strip the other end of the tuxies. Since the rotating spindle unburdens the force needed to pull the tuxies this makes the operating work more ergonomic. Compared with the manual stripping the spindle has the ability to handle about 5 tuxies at a time instead of about 2 at a time which improves the efficiency.

Additionally, the spindle can produce higher quality fiber bundles by using non-serrated knives which results in a lower amount of residual parenchyma, vascular cells and also water content. A higher fiber grade will then generate more income. Furthermore, the non-serrated knife leads to much thinner bundles compared with the manual stripped bundles which are usually generated by a serrated blade.

The traditional spindles are stationary and weigh about 700 kg and are driven by a 2-4 kW engine. Due to the heavyweight abaca farms in inaccessible areas cannot use stationary spindles very easy. Instead, a portable stripping spindle has been developed with a weight of only 90 kg with a gasoline engine using 5 liters of gasoline for every hundred kilograms of dried product. Since the portable stripping spindles are possible to locate in direct connection with the actual farms no transportation of tuxies is needed and the organic residuals can be left as an organic fertilizer. This is not the case with the stationary spindles as the waste leaves from the stripping process end up someplace else other than by the farm.

**Stripping by decortication**
Another semi-mechanical process is decorticating which has the ability to process whole leaf sheaths of abaca by using revolving blades. This comes with both advantages and disadvantages. The productivity rises at the expense of the fiber quality. Since no tuxying is required a time-consuming step in the process can be neglected, though, the product will end up with lower quality since a mixture of different tuxy layers of both primary and secondary fibers are the outcome. Furthermore, the decorticating machine cannot strip a whole piece of the sheath at once, hence a regrip to strip the other side of the in-going piece is still necessary.
Figure 7: A decortication machine with the cap removed in order to visualize the revolving blades

**Productivity of the different stripping methods**

There is a significant difference between various ways of bundle extraction. A hand stripper produces about 20 kg of fiber bundles a day in comparison with 80-120 kg produced by the spindle stripping method. The most efficient way of extraction is the decortication which can reach a production level of 140 kg a day though with a result of lower fiber quality. Considering the total weight of the trunk the stripping process by hand results in a 1% yield of fibers (or 28% of the extractable fibers) while the spindle stripper provides a yield of 1.5% (or 43% of the extractable fibers). The highest yielding stripping device is the decortication machine which has a 3.34% yield considering the total trunk weight or as much as 95% of the total fiber content. The fiber content and yield, of course, vary among the different varieties.

**Drying of fibers**

Next, after the stripping process, the obtained fibers are then either dried under the sun or in a mechanical drying process. The later one is a more abundant method in Central America rather than the Philippines, just as the mechanical stripping. Both which are due to poor financial strength in the Philippines. A vast majority of the tuxies are still being stripped by hand, about 80%, and mostly carried out in the region of Bicol while the residual 20% of the tuxies are being stripped by spindles in regions like Mindanao and Leyte. After stripping, the bundles of fibers contains about 60% of moisture which needs to be dried away as soon as possible to 14% content of moisture to avoid discoloration. Staining will also lower the generation of income due to poorer quality. The bundles are hung to dry in the sun which takes about three hours in optimal conditions though during rain season this could take days.
Baling and grading of fibers

After the drying process, the fibers are transported to the so called GBE which is an acronym for “Grading/Baling Establishment”. The GBEs are firms which further distribute the dried fibers for commercial uses. This includes, just as the acronym implies, grading and baling of the products. The fibers are packed in bales according to standards where one bale of fiber corresponds to 125 kg of fibers. The GBEs have, as for all abaca fiber-related business, to acquire a license to legally operate. The GBEs are sorted into different classes which are corresponding to the numbers of bales that are pressed each year. The classes are sorted as first, second, third and fourth. The first class grading and baling establishments are those who press not less than 30 000 bales per year and the fourth class belongs to those establishments that do not press more than 10 000 bales per year. The licenses are distributed by philFIDA (Philippine Fiber Industry Development Authority) and come with certain requirements. Besides paying the application fee (which varies depending on on the GBE class) the GBE needs:

- at least one baling press
- storage of a minimum of 850 square meters separated from other potential products to be stored
- at least one weighing machine with a certificate of periodical calibration
- at least one classifier

A classifier is a person with a certificate of passing practical tests regarding fiber classification. The practical tests are carried out by the PhilFIDA. Though the classification is not done by any instruments, instead, the dried bundles are sorted in grades qualitatively by visual inspection of the classifier.

The grading system

The fiber grading system is an extensive one considering the Philippine National Standard (PNS/BAFS 180:2016). The grading system first holds the following minimum requirements:

- The tensile strength of the bundles may not underscore 35 kgf/gm (kilogram of force per gram meter)
- Bundles may not be shorter than 60 cm
- The bundles should have a uniform color
- The fiber bundles shall origin from the same kind of stripping
- The bundles cannot be dirty or in any other way contaminated

The parameters of valuation are the origin of the leaf sheath, length, width, color, stripping process and texture of the fibers. This sums up to eight different grades with corresponding numerical codes for hand stripped and spindle stripped bundles (The spindle stripped grading codes have an additional “S” in front of the code)
respectively. A table with the grading system codes summarized and simplified can be found in Appendix, Table 1 and Table 2.

The Abaca Business
The most dominant abaca producer in the world is the Philippines which accounts for an 85% share of the world’s import of abaca fibers while the remaining 15% of the supply is mostly accounted by Ecuador. The abaca fiber is one of the most important agricultural exports in the Philippines. In 2018 Philippines produced 260 056 bales of fibers which corresponds to 32 507 mt of abaca coming out the GBEs. However, the rate of production is larger since not all fibers end up in registered GBEs from registered farmers.

The largest piece of the abaca production sector is the farmers with about 77 500 farms in the country where some are organized in cooperatives. Compared to Ecuador where the abaca production is concentrated to larger industrial farms the Filipino production is carried out by small farmers or cooperatives which are responsible for the farming, stripping and drying processes. As one of the primary agricultural exports the area of land covered by abaca plantations is approximately 127 258 ha and the average land exerted by a single farmer is around 2 ha which measures up to about 2.8 soccer fields. Since the largest sector within the abaca industry is held by farmers working on a small scale the abaca also affects socioeconomic factors among those farmers which is important to consider. In 2004 the average price of abaca fibers was around 0.71 USD/kg where a share of 56% (0.39 USD/kg) went to farmers. In 2019 the fiber price of the higher quality grades is about 2 USD/kg and for the lower quality grades 1 USD/kg.

The abaca market flow is filled with intermediate buyers between farmer to GBE. Usually, farmers supply the local village dealer which further distributes to a town trader storage which in turn provides the GBE with abaca fibers. Due to the lack of knowledge among farmers about the official grading system constructed by the philFIDA no consideration about grades is taken in the first steps of distribution. These middlemen in between farmer and GBE are risking lowering the farmer’s income since higher grades of fibers risk being mixed together with lower grades and hence lowering the total quality of the crude fiber.

During the first decade of the 21st century the abaca industry reached a value of income of around 80M USD per annum and by the year of 2007 around 60 000 MT of abaca were produced. The largest producing region is Bicol which in the third quarter of 2018 accounted for 40.9 % of the total abaca production in the country at that time. Other large shares of the production are held by the regions Eastern Visayas (16.9%), Davao (13.5%) and Caraga (12.0%).

In 2004 around 76% of the fibers produced were going for processing within the Philippines while the leftover 24% of the production went to export as crude fibers.
By 2015 the domestic processing had decreased to 66% of the total production meaning more raw material was exported. Today usage of abaca fibers in tea bags, meat casings and other “special paper products” is making pulping a business area for growing. In 2004 paper products containing abaca pulp like meat casings and tea bags etc were accounting for around 80% of the world’s abaca consumption while the rest was shared by handicrafts and cords.

The largest sectors within the Philippines is the pulping sector which in 2015 accounted for a 57% usage of the amount of fibers going into the domestic market. Another large domestic manufacturing sector is the rope production which occupies a 31% piece of the fibers available for the domestic market. During the years 1997-2006 an annual profit of 80M USD as earned within the abaca industry of which about 82% was accounted by processors, mainly the pulping industry, while the rest came from exports of the crude fibers. However, during the year of 2017-2018 only five licensed (by philFIDA) abaca pulping facilities were active within the country.

The abaca supply and demand
During the last years, the demand of the abaca fibers has been growing internationally. Today the productivity is not sufficient to meet the demands of fibers and fiber products on the international market. In 2019 the gap between the supply and the demand is 25 000 metric tons. This means that with the production of fibers in 2018 which measured up to around 32 000 metric tons an 80% increase in the supply is need to meet the demand. The demand of the abaca fibers along with other natural fibers are also predicted to continue to increase due to a general growing demand among renewable material for environmentally friendly products.

The volumes of production vary within the country but the average productivity is 850 kg/ha which only corresponds to 42.5% of the predicted possible production that is 2000 kg/ha. Today the low productivity makes it impossible to meet the demand. The productivity failing can be described by several reasons. As for example; for a long time the farmers have been dependent on traditional abaca varieties which do not live up to the desired fiber yield, fiber quality and also lack of resistance towards diseases such as Banana bunchy top virus. Due to the decreasing genetic pool projects have been immersed with the purpose of breeding virus-resistant crops. Also, the fiber recovering process has a low efficiency which of course make the productivity suffer. Another factor is the lack of distribution of information to farmers on how to increase the fiber yield by using suitable intercrops.

Challenges
The abaca production has a hard time meeting the high demand from the market. This is due to several factors. One of them is nutrient leaching. Maintaining a nutrition full soil is a common struggle at abaca plantations and depends on multiple circumstances. Another factor is that in some farms the harvest is transported away from the field and therefore none is reimbursed into the ground as a natural cycle of
Both of these factors are prevented by intercropping legumes as mentioned above.

Another major obstacle is several pests of different kinds that can infect the abaca plant. There are five major group of pests; fungal diseases, insects, bacterial diseases, nematodes and virus diseases.

- Fungal diseases are mostly transmitted via water-transported propagules and air-carried spores. Several of the fungal diseases affected the plant so parts of it rot.
- The most common pest organism is the aphids. Usually, it does not cause big damage but it can be carrying and spread virus diseases. An insect that causes a lot of direct damage is the corn weevil. The weevil feeds of the inner part of the plant and an infected plant will die. Other insects that damage the abaca is the slug caterpillar and abaca leafroller.
- Bacterial wilt is a bacterial disease that infects the abaca plant. The bacteria makes the plant wilting and drying out. The disease is carried around to other plants via contaminated tools and rainwater. Affected plants need to be burned.
- Common virus diseases for abaca plants are Abaca mosaic virus, abaca bract mosaic virus and Abaca bunchy top. The two prior diseases spreads via insects, mostly different kinds of aphidis. The last disease, abaca bunchy top is spread among plants directly. When plants are affected by one of the virus diseases they have to be exterminated and the transmitting vector, the insects of example, have to be fought with pesticides. For minimizing the risk of infecting a farm with aphidis PhilFIDA recommend the abaca farmers not to cultivate the abaca close to corn or other plants carringy the pest.

Furthermore, the lack of framing technology and management are contributing to the unfulfilled demand. Without the knowledge of for example intercropping the productivity in the farms cannot reach maximum capacity. Additionally, due to the small size of the scattered farms, the PhilFIDA does not have the capacity to monitor all farms. Therefore the means of reaching out with new knowledge to farmers is limited.

**Discussion**

Abaca is proved to be applicable for many diverse areas and the applications is still growing in number, expanding to new markets. Even though abaca has a long history, it is a resource of the future. As a renewable and relative fast-growing source it has potential of being of great importance for a sustainable future of renewable materials. First and foremost it could contribute to becoming less dependent on fossil fuel by acting as a substitute for fossil fuel based materials. Nevertheless, the future
benefits of producing abaca should no only be reduced to this fact, it could also help increase the livelihood of abaca farmers providing them with a stable income as well as improving the economy for the Philippines in general.

With the objective to suggest ways for the farmers to improve their profit one must begin in the right end. Today the productivity of an average abaca plantation is around 850 kg/ha which corresponds to less than half of the predicted productivity. Ways of increasing the farmers income should therefore not only be finding new applications for the fibers but also to increase the existing production. Since the productivity is much lower than what is predicted one should also focus on that factor. Why is the production so low? Several factors can be identified.

Since the average farms are measuring up to nearly three soccer fields (or two hectares) the farming is managed in a low scale. The problems in productivity would not only be caused by the scattered small farms which makes monitoring the production challenging but also the lack of knowledge about modernization of the farming. Within the abaca farming industry there are poor farmers with a very primitive production of abaca. Experiences from the field trip shows that some farmers do not have much contact with the outer world and hence cannot easily be reached by new knowledge. This rather leads to farmers knowledge about what works or not is being gathered up during a long time of trial and error which of course is a waste of time and resources. This is something that of course affects the productivity negatively.

For example, there are several known ways to enhance the fiber production such as intercropping and fertilization. It is also important to choose the suitable type of abaca for the area it is intended to grow in. Since the abaca production has experienced a loss in genetic diversity farmers could still be cultivating low yielding and low-disease resistant crops. The knowledge about these factors exists for example within the philFIDA which is an authority that partly works for spreading of information regarding the abaca production. Though there seems to be a glitch in the system since not all farmers have this information available. The field trip revealed that the small scale farm in Bicol and also on Marinduque (Boac) had no knowledge about the intercropping system or fertilization of any kind. Even though it has been shown that lessening the sun intensity with 50% with shading trees such as coconut increases the fiber yield significantly.

Along with this, fiber yield enhancement is also possible by using legumes such as Desmodium ovalifolium or Calopogonium muconoides which boost the fertilization. Since farmers have for a long time only relied on the inartificial soil fertility for the abaca cultivation that could also be a dominant factor of the productivity gap where the productivity is 42.5% of the predicted one. To increase the fiber yield by intercropping systems it is therefore not only important to provide the abaca shelter from sun and wind but also to prevent soil erosion due to lack of anthropogenic
fertilization. Though this is information that needs to be broader distributed to farmers in order for them to increase their fiber production and hence their income.

Also the farmers visited in Bicol were not informed about the official grading system since they only use the fibers to make handicrafts by themselves to sell. This shines light on several problems considering the low income of farmers. Since the abaca is organized in layered sheaths that is suitable for different applications and hence corresponds to different prices it is a waste of money in using all of the fibers for making cheap handicrafts. The outer parts of the sheaths are those suitable for making handicraft goods which means that the inner parts could be used for something else and maybe more valuable such as pulp. Therefore it is important to understand that each layer of sheath could correspond to different grades and areas of usage which makes the price of the layers differ. By understanding in which application which layer is desirable optimization of income is possible since this avoids the case where higher value fibers are mixed with lower value fibers in cheaper applications such as handicrafts. This knowledge is today adopted by the GBE that is responsible for the grading. Though since there are farmers without any knowledge about the grading system producing their handicrafts on spot by using all layers they risk to lower their income while mixing high-value fibers into cheaper products.

What also could benefit the situation of the farmers are means to raise the prices of fibers and the fiber products. During the field trip, interviews were made with farmers doing their own handicrafts. The farmers were less motivated to do so due to the knowledge that their products are being sold to higher prices abroad. A more organized community could work against this problem. Since one farmer alone can not demand higher prices for the international companies it is important to organize in cooperatives and force up the prices for those products. That would make it harder for the international importing companies to obtain cheap products and then further distribute it to higher prices making the profit end up far away from the farmers. At the same time this might lessen the exports of handicrafts since the margin of profit to make from the abroad importing companies may decline. With that said there is no easy answer to the problem. Arranging in cooperatives (which today is partly integrated at some places) could also be a solution to decrease the large amount of middlemen between the farmer and the GBE. By arranging in cooperatives that directly delivers fibers to the GBE the incomes from the raw material can also be increased since this avoids farmers without knowledge about the grading system selling their harvested raw fibers to local traders and town traders to a price lower than necessary.

Even though the low productivity of abaca, the Philippines is by far still the number one abaca producer in the world. And since the production can not supply the world demand this offers huge areas of growth within the Filipino abaca sector, where increasing the productivity is an obvious start. Though realizing the growth the future
should not be limited to the case where crude fibers are being exported to be integrated in high-value products abroad. With an increasing productivity the possibilities in making high-value products within the domestic industry are growing. Since the largest piece of the income from abaca products (raw fibers included) comes from pulping this is an evidence of previous reasoning. With a growing productivity and hence an increasing supply a larger share of the produced fibers can be used for domestic pulping which will mean increasing the value of the product instead of just exporting raw fibers.

Since pulping within the Philippines could be a way to add value to the abaca products before exporting it rather than after, the grading system of today also needs to be developed which is something that also has been addressed in several other reports (For example by Moreno and Protacio in their work “Chemical composition and pulp properties of Abaca (Musa Textilis Nee) cv.Inosa harvested at different stages of stalk maturity”).

The minimum length of the fiber bundles to obtain any grade is 60 cm or else it is sorted under “residual”. This is, in the eyes of the farmer, rather counterproductive in some cases. The grading system is a tool for fractionate the different kinds of fiber bundles by their way of extraction, origin within the trunk etc. Since different grades corresponds to different applications of different value this results, as said before, in different value depending on the grade. Though today fiber bundles with less than 60 cm in length is not able to obtain any other grade than “residual” which could make farmers earn less even though these fibers of course can be pulped and hence incorporated in high-value products. This results in an unnecessary decrease of fiber value. For pulping, the length of the fiber bundles are not relevant since the fibers are to be disintegrated anyway. Since pulping opens doors for several applications this generates a higher value of the products. This value should also be represented for the crude fibers that may not be longer than 60 cm and sorted as “residual”. The problem with this kind of grading is that farmers will earn less even though their “residual graded bundles” are compatible with high-value applications through pulping.

Also, due to the increasing awareness in the world about environmental protection the demand of renewable materials and “environmentally friendly materials” is here to stay and will surely continue to increase for a long time. This is a critical time for Filipino abaca industry considering both the productivity and the ability to create high-value products on site without just exporting raw fibers. With an increasing demand of renewable products the demand of natural fibers should of course increase which means that abaca fibers, which are considered as the strongest natural fiber known to man, have a great slot to fill. With companies within the automotive and packaging industry focusing on redesigning their products to lessen the use of fossil fuel-based material with the help of natural fibers one might expect the competition among different fibers to increase. It is known that the abaca have different advantages over
other fibers such as the high tensile strength and the high flexural strength. But those advantages will not be sufficient if a high and steady supply of fibers for biocomposite materials cannot be assured. In an ideal world succeeding in increasing the productivity and managing doing high-value products such as biocomposites in the Philippines will not only contribute to lessen the use of fossil-based material it will also help increase the socioeconomic factors of many poor abaca farmers.

Conclusions

By conclusion, the productivity (kg fibers/ha) is to low to meet the demand and it is crucial to increase the productivity in order to seize the future of abaca on the world market.

Increasing the spreading of information about suitable abaca varieties and intercropping systems to farmers the productivity can be increased. Also, the extraction of fibers needs to be modernized in a way to increase the fiber yield but not decrease the fiber quality.

The farmers’ knowledge about the fiber grade and what grade of fiber that should be used for what product should be increased by a further distribution of information. This can improve the means to optimize the usage of different fiber grades into their most suitable applications. This will reduce the risk of lowering the farmers’ income since this avoids a situation where high-value fibers (of higher grades) are being used in cheap products where lower-value fibers (of lower grades) should be used instead.

Fiber bundles shorter than 60cm should not be classified as the low value “grade” residual because they are well suited for pulping applications. Hence those fibers should correspond to higher value grades.

As the report shows, abaca could not only be used for traditional low-cost handicrafts but also pulping products and biocomposites which could help poor farmers increase their standard of living. By focusing on actually producing high-value products within the Philippines a higher fraction of the profit could be maintained to domestic stakeholders.

Acknowledgement

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We wish to thank various people for their help and support during our field trip to the Philippines. The entire office of Professor Senoro who hosted us and provided us with all the possible help we needed. We also wish to thank everyone whom we have interviewed for spending time to help us understand more about abaca.

Finally, we want to express our appreciation to the Linneus Palme program which is funded by the Swedish International Development Cooperation Agency to enable a great exchange between Mapúa University and KTH. We wish that the program will continue and for future students to get the same opportunity for a similar exchange.
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Table 1: An overview of the summarized official grading system made by the PhilFIDA according to Philippine national standard (PNS/BAFS 180:2016). The table has been simplified for making it more comprehensive.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Extracted from</th>
<th>Fiber strand size [mm]</th>
<th>Color</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF</td>
<td>Inner leaf sheath</td>
<td>0.2-0.5</td>
<td>Light ivory to a hue of very light brown ochre</td>
<td>Soft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Frequently intermixed with ivory white</td>
<td></td>
</tr>
<tr>
<td>S-EF</td>
<td>Inner leaf sheath</td>
<td>0.2-0.5</td>
<td>Light ivory or pale brown to a hue of ivory white</td>
<td>Soft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Frequently intermixed with ivory white</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>Next to the outer leaf sheath</td>
<td>0.2-0.5</td>
<td>Ivory white slightly tinged with very light brown to red or purple streak</td>
<td>Soft</td>
</tr>
<tr>
<td>S-S2</td>
<td>Next to the outer leaf sheath</td>
<td>0.2-0.5</td>
<td>Light ivory to very pale brown with very red or very light purple streaks</td>
<td>Soft</td>
</tr>
<tr>
<td>S3</td>
<td>Outer leaf sheath exposed to sun</td>
<td>0.2-0.5</td>
<td>Predominant color- light to dark red or purple or a shade of dull to dark brown</td>
<td>Soft</td>
</tr>
<tr>
<td>S-S3</td>
<td>Outer leaf sheath</td>
<td>0.2-0.5</td>
<td>Predominant color - light to dark red or purple or a shade of dull to</td>
<td>Soft</td>
</tr>
<tr>
<td>Grade</td>
<td>Description</td>
<td>Density</td>
<td>Color</td>
<td>Texture</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------------</td>
<td>---------</td>
<td>------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>I</td>
<td>Inner and middle leaf sheath</td>
<td>0.51-0.99</td>
<td>Light to very light brown</td>
<td>Medium soft</td>
</tr>
<tr>
<td>S-I</td>
<td>Inner and middle leaf sheath</td>
<td>0.51-0.99</td>
<td>Light to very light brown</td>
<td>Medium soft</td>
</tr>
<tr>
<td>G</td>
<td>Next to the outer leaf sheath or similar leaf sheath source where S2 is obtained</td>
<td>0.51-0.99</td>
<td>Dingy white, light green and dull brown</td>
<td>Medium soft</td>
</tr>
<tr>
<td>S-G</td>
<td>Same leaf sheath that produces the grade S-S2</td>
<td>0.51-0.99</td>
<td>Light brown with occasional streaks of very light green</td>
<td>Medium soft</td>
</tr>
<tr>
<td>H</td>
<td>Outer leaf sheath</td>
<td>0.51-0.99</td>
<td>Dark brown</td>
<td></td>
</tr>
<tr>
<td>S-H</td>
<td>Same leaf sheath that produces S-S3</td>
<td>0.51-0.99</td>
<td>Brown to dark brown Intermixed with substantial portion of fiber with lighter colors</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>In some, color approaches black</td>
<td></td>
</tr>
<tr>
<td>JK</td>
<td>Inner, middle and next to outer leaf sheath</td>
<td>1-1.5</td>
<td>Dull brown to dingy light brown or dingly light yellow, frequently streaked with light green</td>
<td></td>
</tr>
<tr>
<td>S-JK</td>
<td>Inner, middle and next to the outer leaf sheath</td>
<td>1-1-5</td>
<td>Light dull brown to dingy light brown or dingy light yellow with occasional</td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td>Consists of</td>
<td>Otherwise graded as</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
<td>---------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y1</td>
<td>Weak, stained, discolored, and/or soiled fiber</td>
<td>EF, S2, S3, I and G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-Y1</td>
<td>Weak, stained, discolored, and/or soiled fiber</td>
<td>S-EF, S-S2, S-S3, S-1, S-G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y2</td>
<td>Weak, stained, discolored, and/or soiled fiber</td>
<td>H, JK, M1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-Y2</td>
<td>Weak, stained, discolored, and/or soiled fiber</td>
<td>S-H, S-JK and S-M1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O and S-O</td>
<td>Made up of strings and twisted or knotted strands of hand-stripped abaca fibers</td>
<td>Ordinary handmade cords used for tying hanks, bales and binding bundles of loose ungraded fibers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T and S-T</td>
<td>Less than 60 cm in length</td>
<td>Consists of abaca tip cuttings, short, tangled and broked, resulting from sorting during the process of classification</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 2: The grading system shaped by philFIDA for residual grades. Information taken from philippine national standard (PNS/BAFS 180:2016).*
**Abaca varieties:**

*Table 3: Different abaca varieties recomended by the PhiliFIDA* ¹⁸

<table>
<thead>
<tr>
<th>Variety</th>
<th>kg/ ha and year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>For Bicol</strong></td>
<td></td>
</tr>
<tr>
<td>Musa Tex 51</td>
<td>2 084</td>
</tr>
<tr>
<td>Abuab</td>
<td>1 723</td>
</tr>
<tr>
<td>Tinawagan Puti</td>
<td>1 607</td>
</tr>
<tr>
<td><strong>For Visayas</strong></td>
<td></td>
</tr>
<tr>
<td>Linawaan</td>
<td>1 320</td>
</tr>
<tr>
<td>Inosa</td>
<td>1 270</td>
</tr>
<tr>
<td>Laylay</td>
<td>1 090</td>
</tr>
<tr>
<td><strong>For Mindanao</strong></td>
<td></td>
</tr>
<tr>
<td>Maguindanao</td>
<td>2 100</td>
</tr>
<tr>
<td>Bangolanon</td>
<td>1 720</td>
</tr>
<tr>
<td>Tangongon</td>
<td>1 590</td>
</tr>
</tbody>
</table>