

A lush tropical garden scene. In the foreground, a stone path winds through dense, vibrant green foliage, including large-leafed plants and ferns. The background is dominated by a tall, dense grove of bamboo trees, with sunlight filtering through the canopy, creating a bright, hazy atmosphere. The overall mood is serene and natural.

Research paper

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Inhoudsopgaven

- Project

- Introduction
- Objective
- Why Wood

- Methodology

- Wood, Local Indonesia

- Types of wood
- Results/ Findings

- Peri-Urban context

- Criteria
- Importance

- Conclusion

- Literature

Project

How to design a dwelling in a peri-urban kampung with the help of cnc-milling of local wood

Introduction

All over the world cities are expanding and growing in population. Over the last decade the yearly growing rate in Indonesia is approximately 1,2%. This means 3 million more people each year (*Worldometers, 2016*). Bandung is one of the great cities of the Island Java in Indonesia. This city has also expanded over the years and is still growing. Surrounding the city there are communities called 'kampung'. Originally these were traditional communities which lives of the resources of their surroundings. Because of the growth these communities have become part of the dens city. The original green and spacious kampungs have become dens and gray. Now these areas are labelled as 'Peri-urban' and are located between the rural lands and urban city. Because of this densification and new development in technology, new available techniques are used in constructing buildings. Traditional ways are deserted for new technologies. Unfortunately these technolo-

gies are often used in an incorrect and bad way. This makes buildings unsafe and not durable. The structural materials used have also changed from natural to composite materials, which are environmental unfriendly.

Objective

The objective is to improve the building methods that are used in these peri-urban areas and make them more sustainable. A big factor in improving the sustainability is changing the building materials. As mentioned before lots of environmental unfriendly materials are used such as concrete and steel. These materials have a great CO2 emission (*Green, 2013*). I believe that using the local materials like wood can contribute to a positive influence on these areas in sustainability and living conditions. In this paper different kinds of wood are researched with a link to peri-urban areas. The aim of this paper is to get insight in how to use this different kinds of wood in the building environment.

Why wood?

According to Stichting Probos, 60 percent of the land in Indonesia is covered with forest. This results into approximately 100 million acres (*Stichting Probos, 2004*). A big factor of these great amount of forestry are the optimal growing conditions. This factor has a great potential in maintaining a great material stock.

During my career as a student in architecture i have always been fascinated by the material wood, the material that literally grows on trees.

The choice of researching wood has also a lot to do with the sustainable potential of the material. It has a great positive influence on lowering the CO2 emission and the fight against global warming. Also the material can be recycled, reused or chipped and used as land soil.

Methodology

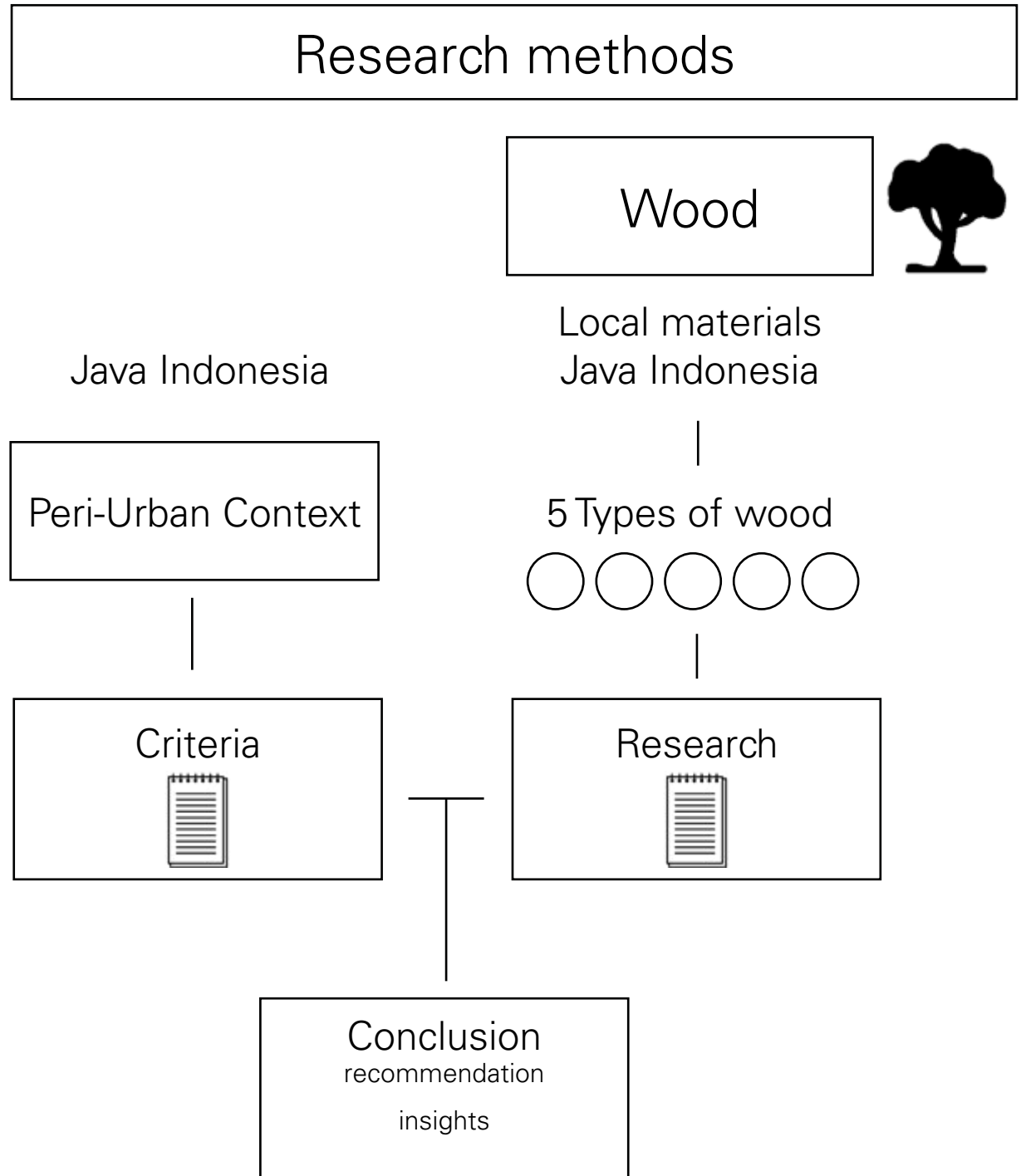
The research methods consist of two aspects. The first is the research on wood and the second is the context of peri-urban areas in Java, Indonesia.

The wood is researched in the context of Java. In order to make a good research a couple of trees are selected to research. In the next chapter this will be more elaborated.

The peri-urban context has already been researched in fieldtrips and literature. With this information criterias are made to make clear what is important in these areas.

The criteria and the research on wood are compared and tested to make a overview in what and how the wood is used properly in the context.

The research will conclude with a recommendation and several important insights



Wood, Local Indonesia

Types of wood

Indonesia is the country with the second largest biodiversity in the world. Many different kinds of tropical woods are grown which come from a lot of different species. This part of the research will focus on a couple of species which are most used in the context of Java, Indonesia. These types of wood will be investigated from the growing stage to manufacturing of timber.

In Indonesia many hardwood types are grown. A selection of types is made on the grounds of local material costs and availability on the Island Java.

The different types of trees are categorized in 5 types. Mahogany, Sengon, Rubber tree, Coconut palm, Bamboo.

One of the chosen types is not a wood but a type of grass. This type, bamboo, is incorporated because its similarities with wood and great potential.

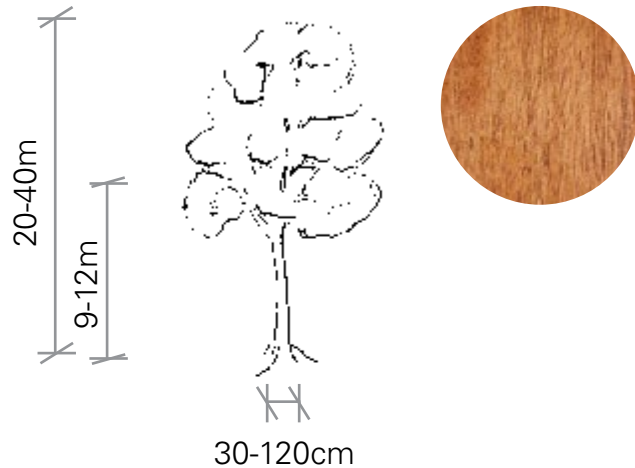
Types of wood:

Mahogany	(hardwood)
Sengon	(soft-wood)
Rubber tree	(semi-hardwood)
Coconut wood	(semi_hardwood)
Bamboo	(type of grass)

For each type of wood the corresponding tree is elaborated. Aspects such as growing speed, density and measurements are researched. With this ground information the possibilities of processing it into a building material is drawn out. Several products are more elaborated than others.

Mahagony

Mahoni, *Swietenia mahagony*



Density =	495-545 kg/m ³
Price per m ² =	1,6 - 3,0 million IDR 108 - 204 Euro
Growing period=	20-40 years

The Mahagony tree is a native species from Indonesia. The tree can reach 40 meters in length and it has a broad crown of leaves. The tree has a trunk diameter which can reach up to 120 centimeters. The tree consists of a high class hardwood. The tree is mainly used for its wood, but during the growing process the tree functions as sun shading (*World Agroforestry Centre, 2009*).

Price

In the tropical forests of Java the Mahagony tree is common. This has great influence

on the price. Even though it is a rather slow growing tree, the availability ensures the lowering of the price. Compared to Teak as one of the most expensive hardwood, the Mahagony is almost three times as cheap. Teak wood with a rate of approximately 6-8 million Indonesian rupiah compared to mahogany with a rate of 1,6-3 million rupiah. In the price chart the prices of different wood types are compared (*Harga Kayu, 2016*).

Resistance

The hardwood which the tree produces comes with good resistance. It's natural properties have a resistance to pests and water (*Fern, 2014*).

Products

Wooden beams

Because of the big dimensions and the



strong core of the tree, big peaces of wood can be extracted and used with minimal processing. The wood is cut into beams with various sizes. These beams are traditionally and nowadays used as structural elements.

Plywood and veneer

Veneer is extracted from the wood and used for finishing purposes. The beautiful red/brown colour has a luxurious appearance. This veneer is often from older trees, younger trees are sometimes used for plywood. The plywood sometimes consists of different kinds of wood. Meranti merah is a light red hardwood species that is often used in making plywood. Because the many cut down trees this is now a endangered type of wood . The prices and availability of Mahogany are much more promising than that of Meranti.

Traditional use

In a traditional kampung called the Baduy, the Mahagony wood is gathered in the direct surroundings. With traditional working methods the wood is cut into beams and connections are carved by the people themselves with great details. Without any chemical treatment the beams are used for the main structure of their houses. The main structure of these houses will be used

Sengon

Albasia, *Paraserianthes falcataria*

for about 10 years. In the images below the dark brown beams and columns are of aged mahogany wood. The secondary light wooden structure is Sengon wood. This is discussed in the next chapter.



Density = 230-500 kg/m³
Price per m² = 0,5 - 1,0 million IDR
34 - 68 Euro
Growing period = 6-15 years

The Albasia tree, also called the 'Miracle tree', is one of the fastest growing tree types in the world. In his first year the tree can grow up to 7 meters. Because of it's fast growing property the wood is soft and not very durable (*World Agroforestry Centre, 2009*).

Price

Majority of the trees grown on Java are Albasia trees. Due to the fast growth it is a constant income of softwood. The great availability of the type of wood makes it a

very cheap one. The price per square meter of timber is below the 1 million rupiah, that is about 68 Euro (*Harga Kayu, 2016*).

Resistance

Without any treatment the timber is very vulnerable to pests and weather. This is because the grain and density is lower than normal tree types. The wood is not preferably used for main structures and in damp places.

Structural properties

The wood of the Albasia tree is a softwood kind. The timber is very light but for a softwood kind it is quite strong. Sometimes the wood is used in structures, but often hardwood types are used instead. The wood has a density that various from 230 - 500 kg/m³.



Products

The Albasia wood comes in many forms. Because of the great availability of the material many different products are made.

Albasia wooden beams

The cheapest way is to dry and saw the logs into beams. Because the tree has medium to large dimensions a good range of measurements for beams are available.



Albasia plywood and block-board

Also all kinds of board materials are made from this wood. By using veneer and small battens of wood, products such as block-board and plywood are manufactured. The transformation improves the structural strength of the material and makes it easier to be applied in construction.



Albasia fibreboard and densityboard

With the use of shredded flakes and dust board materials are made. The boards are pressed together with resin to produce the products. These boards have lower structural properties compared to plywood. On the other hand the waste material of sawing the wood is used.



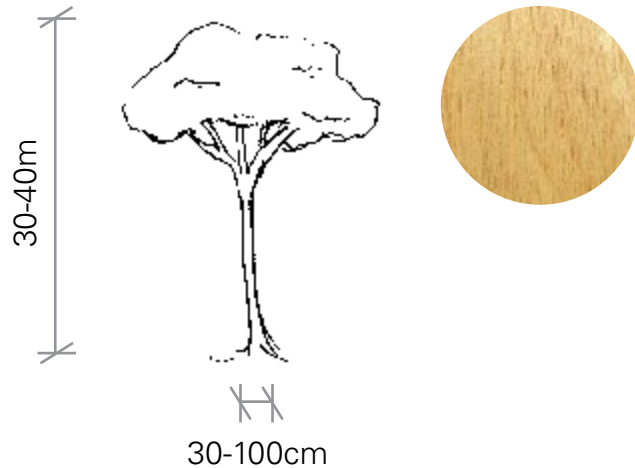
Use tradition

In the traditional tribe called the Baduy the structure of houses consist also of the Alba-

sia wood. With natural treatment these pieces are used in the form of beams. Because the quality of the timber is not as good as the Mahagony, this wood is more used as secondary structure elements and finishing

Rubber tree

Karet, *Hevea Brasiliensis*



Density = 560-640 kg/m³
Price per m² = 1,0 - 2,0 million IDR
68 - 136 Euro
Growing period = 22-30 years

The Rubber tree, also called *Hevea Brasiliensis*, has always functioned as rubber producer. The tree comes from Brazil and is only grown on plantations. The rubber is extracted from the trees for a period of 25 years. When the rubber is no longer produced the tree needs to be replaced. In the past the wood of the cut down tree was not used and often burned down. This changed when it was discovered that the wood has good properties. The wood is thereby a by-product of the rubber production. This makes the material very sustainable. Next

to the nice functional properties the wood has a nice yellow/golden appearance (Killmann, 2001).

Price

In the wood market in Indonesia this type is still quite new. Because the trees are planted mainly for the rubber, the wood is of less importance and sold for a cheap price. The price of the wood is 30 percent cheaper than Meranti red wood (Killmann, 2001).

Resistance

The wood from the rubber tree has good resistance to weather conditions. Because of its dense grain the material has minimal shrinkage. This dense grain also benefits the resistance towards pests.



Structural properties

Even though the material does not have the look of a hardwood, the strength of the timber is comparable to that of teak wood. The timber is also easy to steam bend which can contribute to the structural application of the material.

Products

Rubber wood beams

In constructions rubber wood is not commonly used in Indonesia. Even though Indonesia is one of the countries with a lot of rubber tree plantations. Because of this there lies a great potential in using Rubber wooden beams.

Rubber wood finger-joint boards

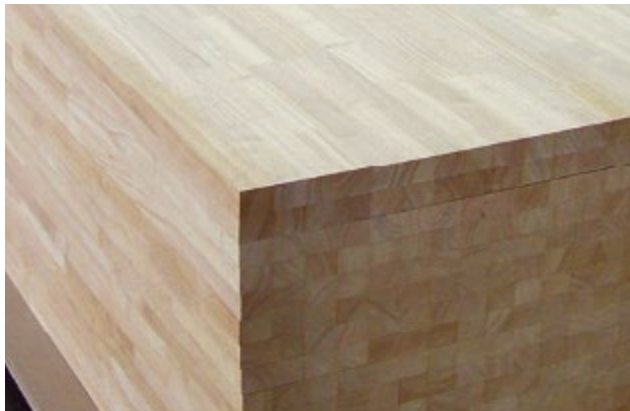
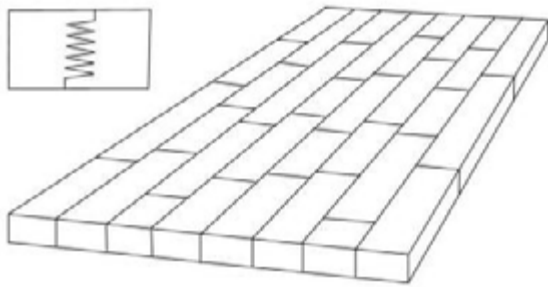
One of the more popular products are the wooden finger-joint boards. This product has a more luxurious aspect because of the more expensive manufacturing process. The quality of these boards is very high that results in high prices. These boards are now often used in staircases and non structural indoor walls (DB Hardwoods, 2016).

Rubber wood particle board

A less expensive way of making board material is the particle and density boards. Research (Bron) has shown that using rubberwood flakes can increase the bending strength value (Amini, 2012).

Coconut palm

Kelapa (glugu), *Cocos nucifera*



Density = 200-850 kg/m³
 Price per m² = 2,0 - 3,0 million IDR
 136 - 205 Euro
 Growing period = 60 years

The coconut wood comes from the coconut palm called *Cocos Nucifera*. The tree is primarily planted for the production of coconut. Secondly the coconut wood is used for constructive elements. The tree has a special structure that consist of a soft inner core and hard outer core. The tree has a cylindrical shape and has no branches. Because the timber is a by-product people label it as a 'sustainable' product. Next to the timber of the tree the coconuts can be used to make building products (Killmann, 2001).

Price

The life span of the tree is about 60 years this makes the timber expensive. However the production of coconuts as its primary purpose can reduce the costs while growing the tree.

Structural Quality

The quality of timber from the tree is divided into three. The outer core consists of a hard kind of timber that is often used for constructive elements. The inner core has a soft quality which has non-load-bearing qualities. In between the timber has a medium strong quality. Because the stem has no knots, the wood quality does not show weaknesses. In the image below the differ-



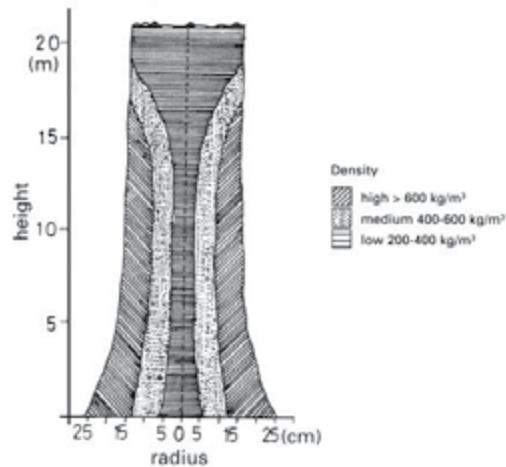
ent parts are illustrated with the density. Resistance

The coconut palm has no natural resistance to attack by insects and fungi. The core of the tree is overall wet and vulnerable. One of the big threats is the Rhinoceros beetle. When this pest breeds in the timber it can cause for big problems. The wood should be treated with water and pest repellent materials immediately after it is cut and sawn. Without any treatment the soft wood decays within weeks as the hard wood has 2 to 3 years (Killmann, 1996).

Products

Coconut wood beams

Wooden beams from the coconut palm are gathered from the outer core. This limits the dimensions to about a maximum of 100x50mm. On the image below it is shown



how the logs are serrated to divide the different parts of the palm. The parts with the letter A are the strongest en best pieces for structural purposes (Killmann, 1996).

Coconut husk board

Recent research have shown that the husk of the coconut can be used to make a sustainable board material. The husk of the coconut is the hard hairy shell also called 'coir'. The coconut is mainly used for its milk what makes the husk a waste material. A material called Ecocoboard consist of 100 per cent natural products. Without any glue or chemicals these boards are made. This makes the process less expensive because normally 30 per cent of the costs are glue and chemicals. The structural quality of the board material is comparable to other board materials (Wageningen University, 2016).



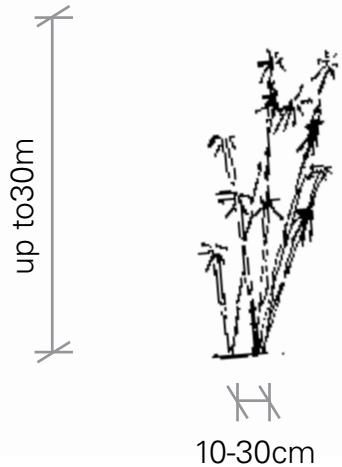
Coconut wood particle board

To produce particle board from the coconut wood, the whole trunk with the bark is used. This makes good use of all the resources because often the soft core and bark are not used because of the bad quality. Unfortunately this way the overall structural quality gets lowered. Also the process costs are higher compared to only sawing and treating the timber.



Bamboo

Bambu, *Bambusa*



Price

Bamboo as a raw material is very cheap, This is linked to the fast growing process. A raw bamboo stalk with a diameter of 12 can cost 10.000 to 20.000 rupiah. Treated bamboo rods are sold for about 100.000-200-000 rupiah. This is 10 times as expensive. The manufacturing of bamboo into new products can be quite difficult. This is mainly because of the hallow and organic features of bamboo. The process becomes complicated and long. That is because treated and adapted bamboo products can reach high prices. The high prices are also caused by uncommon use of these products (*"Harga Kayu", 2016*).

Density =	500 - 850 kg/m ³
Price per rod =	10.000 - 200.000 IDR 0,70 - 14 Euro
Growing period=	3-5 years

Bamboo is not a tree type but a type of grass. In the botanical garden it is called 'Bambusa'. Very fascinating about this type of grass is the growing speed. Bamboo can reach his full grown stage within 5 years. Compared to other grass types its stalks have great strength and are comparable to wood types. When fully grown these are strong enough and can be used as a structural material. Because of this many mistaken the species of being a kind of wood (*Bamboo Garden, 2016*).



Resistance

Bamboo has naturally a quite good resistance to water. But to pests it is much more vulnerable. Because of its great pores eggs of the Powderpost beetle and termites can be laid inside. Without treatment the wood is very vulnerable to these pests. For better pest and weather resistance the stalks are treated with e.g. Borax. The stalks can also be treated in a natural way. When cut down the stalks are kept in water for a couple of months to produce resistance (*Schröder, 2012*).

Structural properties

For its rapid growing speed the bamboo stalks have great strength. When the stalks are cut and dried they are often used in construction and sometimes in the structure of buildings. On Java Indonesia the most common used bamboo type with good strength is the 'Petung' with golden/yellow features.

Products

Bamboo stalks

Traditionally bamboo stalks are used in building houses. Nowadays the material has a more temporary function like support in construction. Bamboo stalks are sold in various sizes from diameters from 10 to 30

cm with a length of approximately 7 meters. The rods are sold with or without treatment.

New Products

If we compare the bamboo to the wood species we can see that it has a hollow structure instead of a solid one. Because of this, solid beams can not be cut out of the raw material. This is why new building products are developed.

Bamboo plywood

To make plywood which can be used easily in structures the bamboo manufactured. With splitting methods small straight battens can be produced. The battens are combined and laminated to form a sheet. Often these plywood consist of 3 layers as shown in the image on the right. The bamboo plywood has a strong structural quality. When cut by laser or router it is makes nice and clean cuts .



Bamboo beams

For making structural beams out of bamboo, two methods are used. The first one is press the split battens into a beam. The second is using a more dens press to make a beam out of bamboo fibers. Normally the maximum length of a manufactured beam is about 2,5 meters. But with finger joint connection it is possible to exceed this length.



Bamboo flake- and densityboard

A next step adapting bamboo into new products is using flakes and dust. These are pressed together to produce board material. Flake board has better structural properties than density-boards which consist of smaller grains. This manufacturing process is cheaper than that of bamboo plywood and beams (*Eco Logic, 2016*).



Peri-Urban context

Criteria

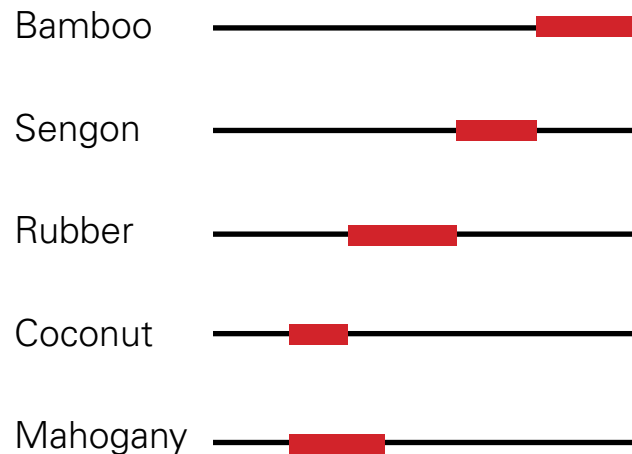
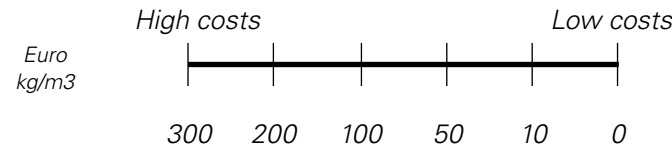
With the research results of local Indonesian wood types and building materials a great amount of information is available. With focusing on Peri-urban context a more detailed outcome is produced. On the basis of the peri-urban context criteria are made. These criteria are used to test the different types of wood. With this information an overview is made to make clear what type of wood is preferred.

With the context in mind 10 aspects are created to test the results. Every aspect is shortly introduced and explained. With this in mind charts are made to rate the different types of wood.

- Costs
- Growing speed
- Growing other products
- Structural properties
- Resistance pests
- Resistance weather
- Weight
- Dimensions
- Processing into plate material
- Life-span

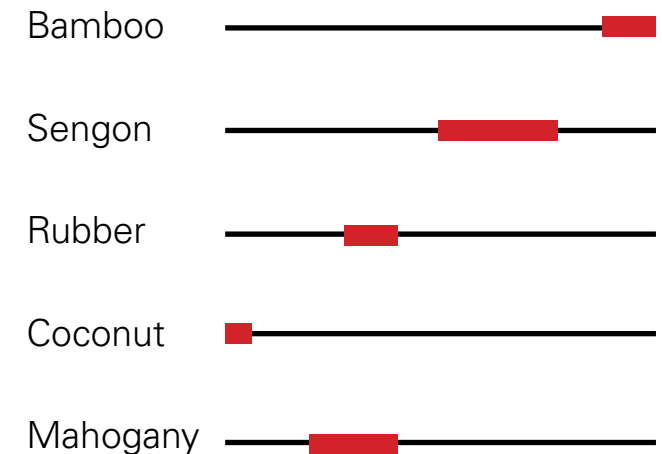
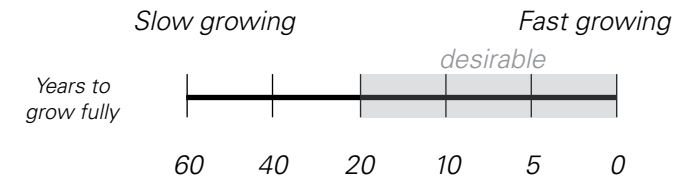
Costs (raw material)

Within the context of peri-urban areas inhabitants do not have a great amount of income. Hereby lowering the costs is a preference. The different kinds of wood are analyzed with the costs of the raw building components like beams and sawn pieces of wood. Costs are researched by the currency in Java Indonesia and then converted to Euro.



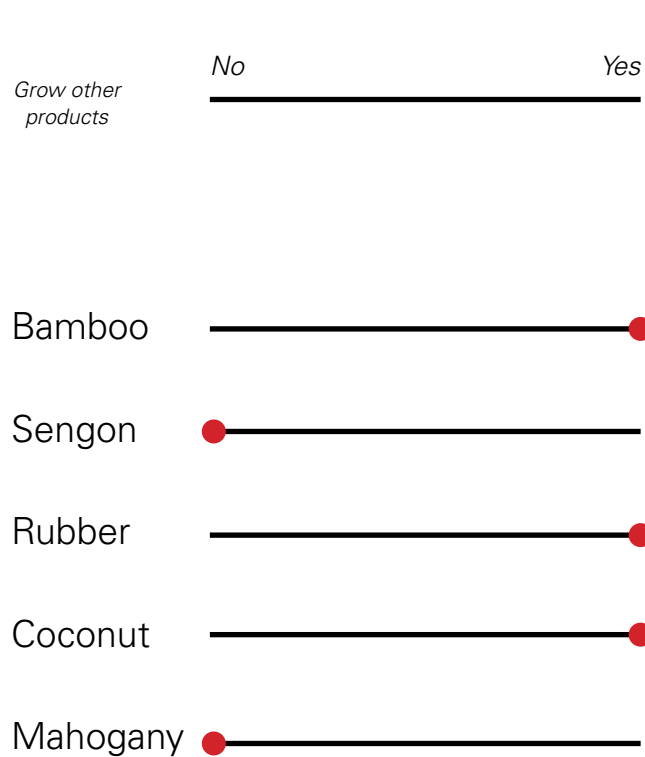
Growing properties

Aspects of growing such as speed and spacing can contribute to a sustainable factor in peri-urban areas. With the possibility of growing trees by the inhabitants themselves these aspects are of great importance.



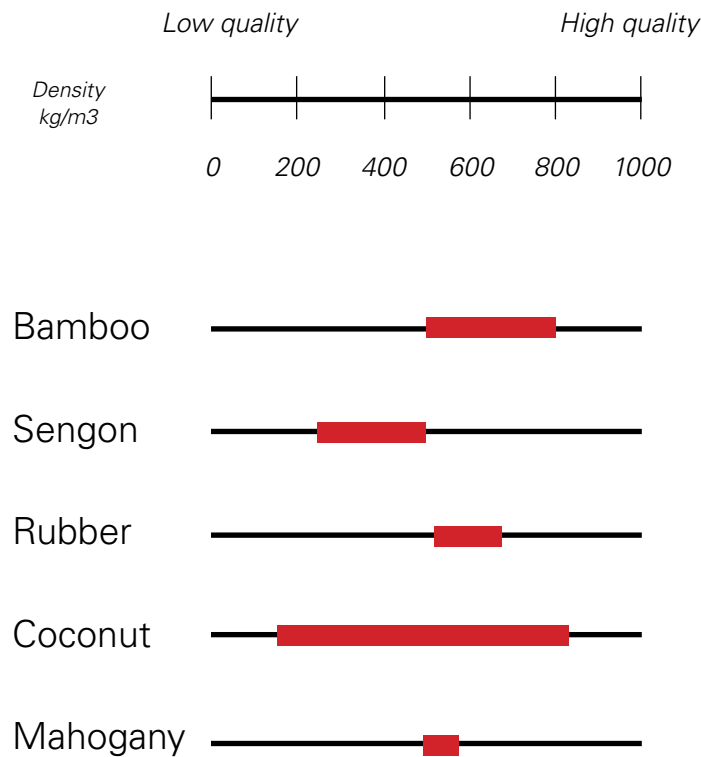
Other products

When growing trees not only wood can be extracted from the trees. Some tree species grow fruits or produce other products.



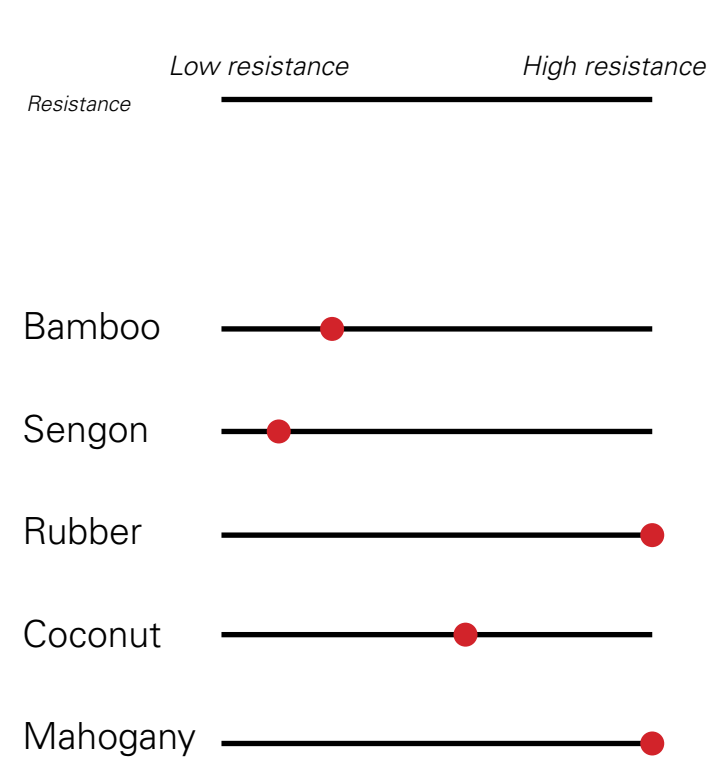
Structural properties

All kinds of wood have their own natural structural properties. For structural safety it is important to know what kind of wood can be used in structural elements.



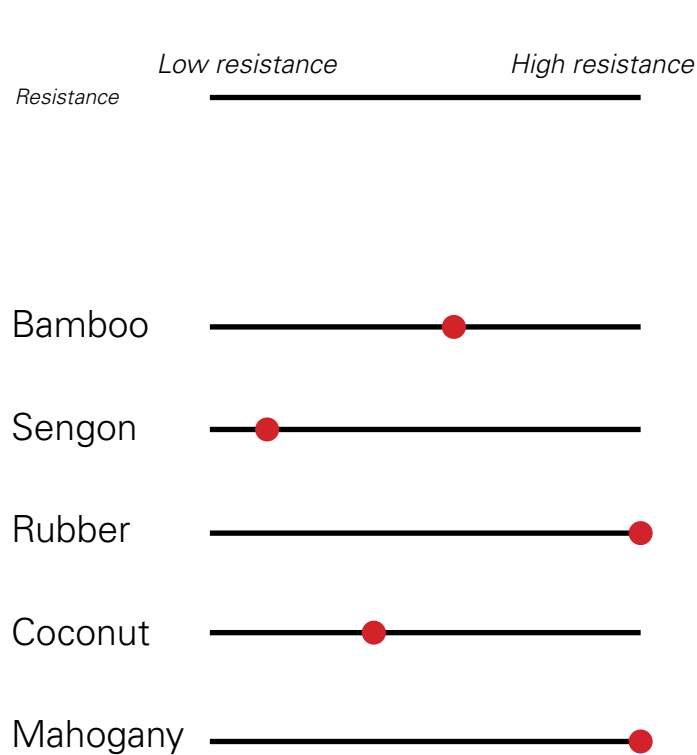
Resistance pests

All wood types are threatened by pests. Almost all wood that is used in the structure of a building are treated. Some species have a better natural resistance to pests. This leads to less treatment or more durability.



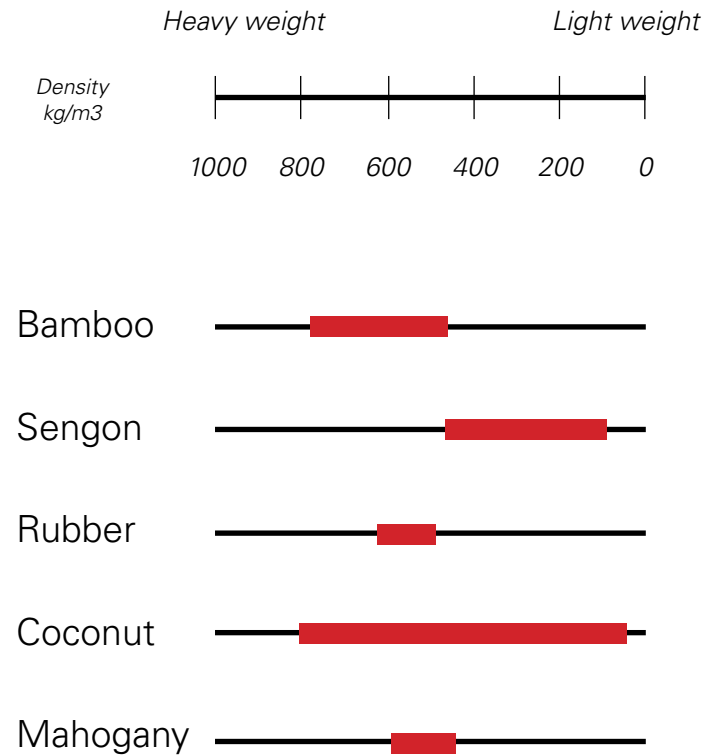
Resistance weather

Weather such as moist, water and damp can be a thread to wooden building elements. Treatment is used for meeting the resistance requirements but some wood types have a better natural resistance than others.



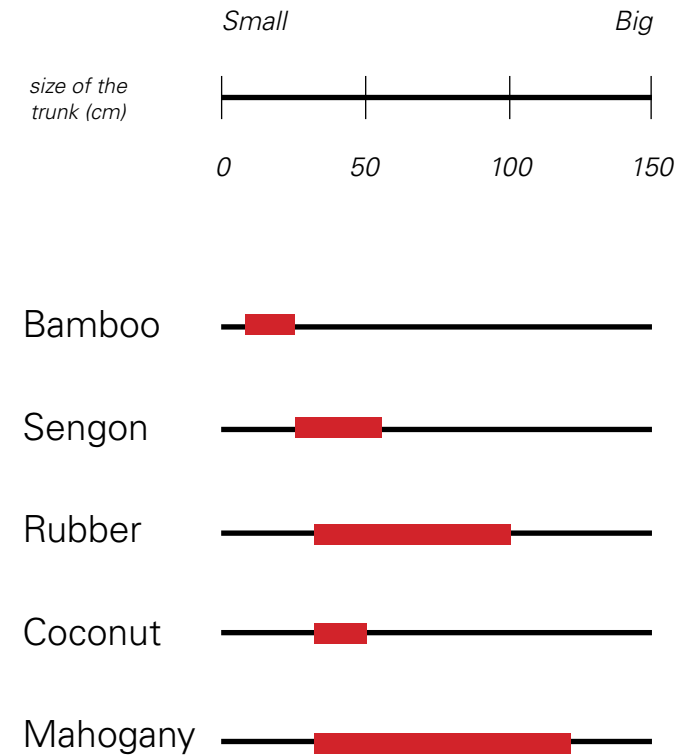
Weight

In the peri-urban context building components must be put together without heavy machinery. Hereby the weight of the wooden components is preferred to be as low as possible. Not all species have the same weight, thereby a range of weight is shown in the diagrams below.



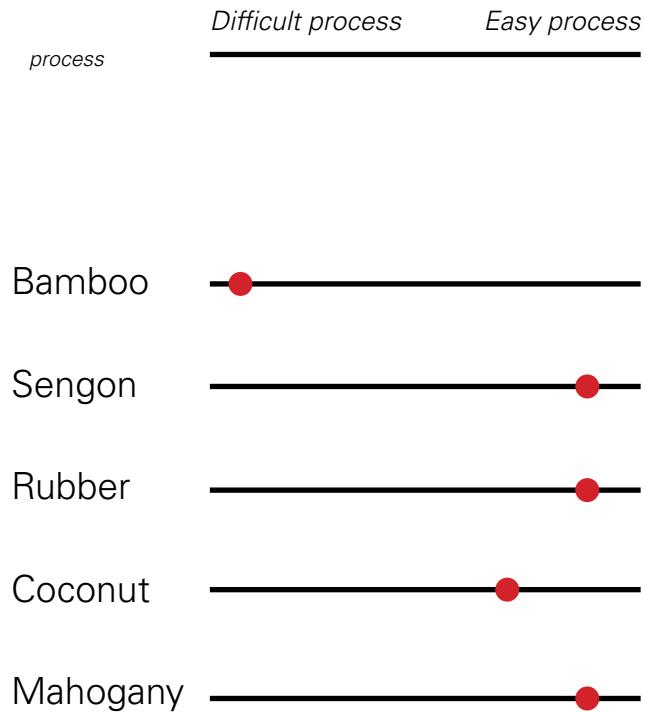
Dimensions

When extracting wood from trees, the size of elements are limited to the size of the trunk of the tree. This has influence on the application of the wooden elements.



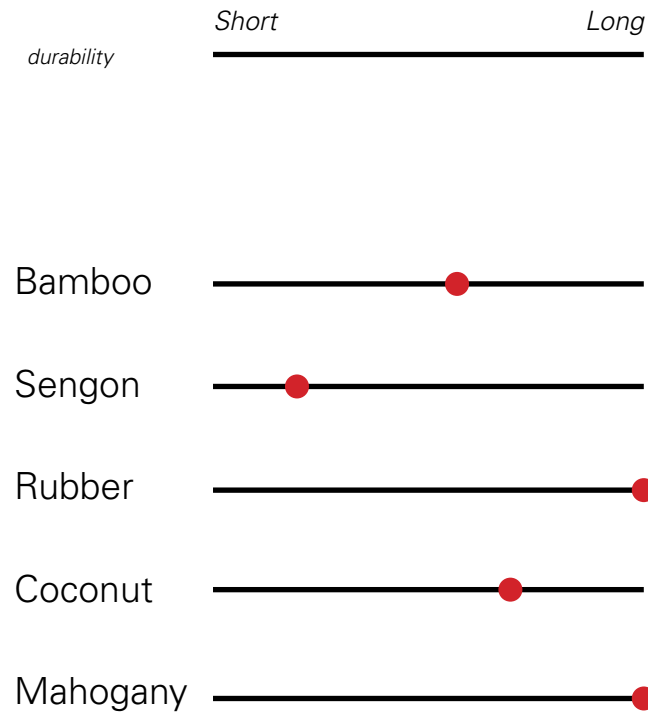
Processing into plate material

When using cnc-milling technique, the process of making plate material is very important. Some wooden species are easily made into these components then others.



Life-span material

All different types of wood have their own durability. This information is necessary for deciding on a temporary or more permanent building components.



Importance

Weight

The previous chapter gives an overview on the several aspects and different kinds of wood. This creates a tool for deciding on using a particular kind of wood. In this chapter we try to figure out which wood type scores the average best in all aspects.

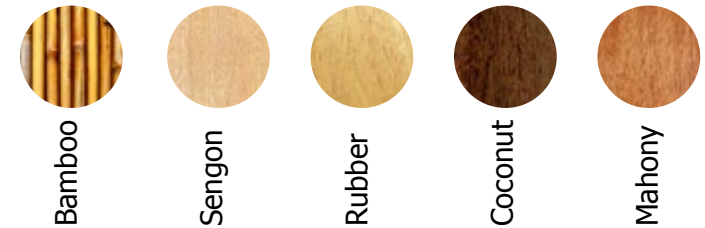
Before making a conclusion which wood is the best, the importance of the researched aspects of wood is researched. By comparing all the aspects with each other, a ranking can be made which is more important. In the scheme below the aspects are put against each other. When there is a '1' the horizontal stated aspect is better then the one in the vertical. In the column. In the end the numbers are added up to give a total score. From this score a division is made and the aspects are grouped in three different

	Costs	Growing properties	Other products	Structural prop.	Resistance pests	Resistance Weather	Weight	Dimensions	Processing	Life-span	Total	Weight
Costs	0	1	1	1	1	1	0	1	1	1	7	+++
Growing properties	1	0	0	0	0	0	1	1	1	1	5	++
Other products	0	0	0	0	0	0	0	0	0	0	0	
Structural prop.	0	1	1	0	0	0	1	1	1	1	6	+++
Resistance pests	0	1	1	1	0	1	1	1	1	1	8	+++
Resistance Weather	0	1	1	1	0	0	1	1	1	1	7	+++
Weight	1	0	1	0	0	0	0	1	1	0	3	++
Dimensions	0	0	1	0	0	0	0	0	0	0	1	+
Processing	0	0	1	0	0	0	0	0	1	0	2	+
Life-span	0	0	1	0	0	0	1	1	1	0	4	++

rankings. This ranking determines the weight of importance of the aspect. For making the final score this weight is incorporated in the scheme below.

Total Score

The next step is adding up the score. First the wood types are ranked from 1 to 5 for each aspect. In the scheme below these scores are added up and ranked. But this is without using the weight of importance. By multiplying the scores with the ranking of importance a new score is found. Still the best option is using rubber wood, but on the third place bamboo becomes more important then mahogany wood.



	Bamboo	Sengon	Rubber	Coconut	Mahony
Costs	5	4	3	1	2
Growing properties	5	4	3	1	2
Other products	5	0	5	5	0
Structural prop.	5	1	4	5	3
Resistance pests	1	1	5	3	5
Resistance Weather	3	1	5	2	5
Weight	1	5	2	1	4
Dimensions	1	3	4	3	5
Processing	1	5	5	4	5
Life-span	3	2	5	4	5
Total score	30	26	41	29	36
Ranking	4	5	1	3	2

Total score x margin	62	50	81	52	74
Ranking	3	5	1	4	2

Conclusion

Recommendation

Researching the all kinds of wood in combination with the chosen context a couple of insights and recommendations can be formed.



Mahogany

Of the researched tree types the mahogany is one of the bigger trees with a large trunk. This gives the opportunity to extract large pieces of wood. These dimensions are ideal for large beams and columns. Locals can extract beams themselves for reducing the costs. Also the natural resistance is good, opportune for structural purposes.



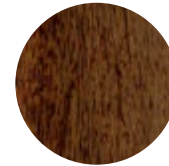
Sengon

This light wood product has the lowest structural and resistance properties of all the researched trees. With its short life-span it does not score high on the charts. This wood is however very popular in Indonesia. The reason is that it is one of the fastest growing tree, and it is grown a lot in Indonesia. The prices for the wood is very low and so this wood is best used in temporary and secondary structures.



Rubber Wood

The wood that is extracted from the rubber tree has great similarities to mahogany. It has good properties of resistance and dimensions. The one extra that this tree gives is the production of rubber. The by-product reduces the costs with producing and selling rubber.



Coconut Wood

The coconut wood have different parts with different properties. Extracting this wood comes with uncertainty of quality. The costs of this wood are high, this is because of the long life-span of the tree. But with the production of coconuts costs can be lowered. With the coconuts other products like coconut husk board can be produced. This makes the long growing period more attractive.



Bamboo

By looking at the context with a possibility to be self sufficient, the growing properties and costs play an important factor. By for instance growing own resources expenses can be decreased. For growing own resources the growing properties must be promising. Bamboo has in each of these factors a great potential. It's fast growth and small growing space are opportune for growing at home. Also the bamboo can be used for other products like textiles and food. The only problem with bamboo is that the process is more labor intensive than others. Also a problem with processed bamboo products is that they can be heavy. This is not ideal for do it yourself assembly.

Combination of woods

The results of the research show that every type of wood has it's benefits. I propose in using these different wood types and combining them in a hybrid structure for dwellings. Growing the plants within the community can lower the costs and probability of wooden buildings. In future designs this paper should be a reminder what kind of wood can be used in structural and finishing purposes in the context of Indonesia.

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