Productivity of Pangi (*Pangium edule* Reinw.) and biodiversity of agroforestry systems at various altitudes in Toraja Regency, South Sulawesi

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**Abstract.** There are two important things that farmers consider in selecting and developing plant species in their agroforestry system, namely productivity and suitability to the site. This study aims to determine the productivity of the pangi crop and the biodiversity of the agroforestry system at different altitudes. This research was conducted from June to November 2018 at three different altitudes, namely in Lembang Palesan (Rembon District) which represents an altitude of <600 m above sea level, Lembang Turunan (Sangalla District) which represents an altitude of 800-850 m above sea level, and Lembang Gasing (Mengkendek District) which represents an altitude of >1000 m above sea level. The research method used is a survey method with the placement of sample plots by Purposive Sampling. The sample plot size is 20m x 50m or 0.1 ha. At each different altitude, 10 sample plots were made, so the number of sample plots was 30. The parameters measured were pangi fruit production, tree diameter and height and recorded all plant species in the sample plot. Data analysis was carried out quantitatively and descriptively, while agroforestry system plant species diversity was identified using vegetation analysis methods. The results showed that the fruit production of the pangi plant, density, LBDS and diameter of the pangi tree were significantly different at each different altitude and the largest was at an altitude of 800-850 m above sea level, but the number of plant species and the diversity of plant species at each altitude were relatively the same in the medium category, as well as the density of all types of plants, and the average height of pangi trees were not significantly different at each different altitude. Thus, it is not recommended that pangi crop be developed at an altitude above 850 m above sea level.

1. Introduction
Pangi plant (*Pangium edule* Reinw.) is one of the multipurpose tree species and is very popular with the public because it can produce fruit that can be consumed. Pangi fruit and seeds that have been processed can be made into vegetables and flavoring for meat soup (sop rawon) which is very tasty and has the potential to be a meat and fish preservative to replace formaldehyde [1]. The Toraja people process the fruit of the pangi plant into 3 product forms, namely kaloko or paleak (dried pangi flesh), kolona (dried pangi seed coat), and pamarrasan (fermented pangi seeds). These three forms of pangi fruit products are very popular with the Toraja people, so that apart from being consumed themselves, they are also sold in the market as a source of farmers' income. This is what encourages the Toraja people to plant and develop it on their agroforestry land.
In addition to the fruit used for various purposes, the bark and leaves of Pangi are also used for fish poison and natural pesticides [2]. Fresh pangi leaves can be used to preserve meat for several days. The freshness of the meat is maintained and insects are rejected [3]. Pangi leaves contain alkaloids, flavonoids, saponins, tannins, quinones, steroids, and triterpenoids [4] and secondary metabolites that have the potential to become biopesticides [5]. Saponin and alkaloid compounds in pangi leaves have the potential as a stunning substance in fish. The best concentration of pangi leaf extract is 2500 ppm with the optimum time of transportation for 2 hours with 100% survival [6]. Even the pangi fruit has the potential to become a raw material for biodiesel production in the future and it is extraordinary to find the properties of biodiesel oil that can be used in cold climates [7].

Understanding the factors that influence the growth of trees and their fruit is very important for silviculture experts because they are considered in the management of agroforestry systems, especially the selection of plant species. One of the environmental factors that affect tree growth and fruit production is the altitude factor. The theory says that a plant species is only able to develop and produce fruit optimally only at a certain altitude range. The practice applied by the community is not like that because usually they only follow their neighbors or only see the success of others. This is the reason why this research was carried out, to determine the upper limit of altitude for good production for pangi plants.

The agroforestry system as one of the oldest forms of land use has also been practiced by the people of South Sulawesi as Dare' and Bela which means mixed garden [8]. The people of Tanatoraja have practiced the agroforestry system in order to obtain their daily needs in the form of food, firewood, animal feed and carpentry wood.

Forest areas in the Sulawesi region are endowed with rich flora and fauna with a high diversity and some of them are endemic because of their position between the Wallace and Weber lines. This abundant species richness is the main capital for farmers in selecting and planting various types of plants in their agroforestry systems [9]. This factor is one part that will be revealed in this study. The high species diversity in the Sulawesi region is not only limited to carpentry-producing trees such as Eucalyptus deglupta, but also to high diversity in food-producing plants such as pangi (Pangium edule), asa (Captanopsis sp.), tarra (Artocarpus spp.), and patikala (Etlingera elatior). The people of Tanatoraja usually use this type of plant as an alternative food source in case of food shortages, for example crop failure. Forest food contributes to food quality and food diversity and serves as a safety net in times of food scarcity [10].

The practice of land use by farmers is by planting uru, Kayuangin, and Pangi plants which have high and wide crowns, while under the Kayuangin and Pangi canopy, farmers plant coffee plants (Coffea spp.) whose silvic character requires shade to grow and produce better. The lowest canopy layer near the soil surface is used to plant taro and sweet potato plants whose silvic properties are shade tolerant. Thus, it can be understood that the good practice of agroforestry systems can produce several commodities that have high economic value and are environmentally friendly. The same thing was stated by [11] that the agroforestry system itself is not only to increase land productivity, but also to protect land from damage and prevent soil fertility decline through the "nutrient pump" mechanism, so that the sustainability of the system can be well guaranteed.

Research on the productivity of Pangi (Pangium edule Reinw.) and biodiversity in agroforestry systems in South Sulawesi is still very rare. Even research on the productivity of pangi plants at various altitudes in the agroforestry system in Tanatoraja Regency has never been carried out. For this reason, research on the productivity of Pangi (Pangium edule Reinw.) and the biodiversity of agroforestry systems at various altitudes in Toraja Regency, South Sulawesi needs to be carried out.

2. Materials and methods

2.1. Study area

This research was conducted from June to November 2018 in three Lembang (villages), namely in Palesan Village (Rembon District) which represents an altitude of <600 m above sea level, Turunan
Village (Sangalla District) which represents an altitude of 800-850 m above sea level, and Gasing Village (Menkendek District) which represents altitude >1000 m above sea level. For more details, it can be seen in Figure 1. The three villages selected as research sites are centers of pangi crops development in Tanatoraja Regency. Pangi is one of the community's mainstay plants besides coffee, so this plant is always found in their agroforestry gardens. Pangi crops are planted by villagers in their agroforestry gardens in the form of random mixtures with various types of plants, both food-producing plants such as sweet potato, cassava, taro and building wood-producing plants, such as kayuangin (*Casuarina junghuniana*), suren (*Toona sureni*), uru (*Elmerellia ovalis*) and fodder crops. Thus, Pangi crops are planted together with other plants with irregular spacing.

**Figure 1.** Research locations in three Lembang (villages), namely in Palesan Village (Rembon District), Turunan Village (Sangalla District), and Gasing Village (Menkendek District), Tanatoraja Regency, South Sulawesi.
2.2 Data collection
The research method used is a survey method with the placement of sample plots by Purposive Sampling. The sample plot size is 20m x 50m or 0.1 ha. At each different altitude, 10 sample plots were made, so the number of sample plots was 30. The parameters measured were pangi fruit production, tree diameter and height and recorded all plant species in the sample plot. Data analysis was carried out quantitatively and descriptively, while agroforestry system plant species diversity was identified using vegetation analysis methods.

The common name of each plant species was obtained from local experts and the scientific names were sourced from previous studies in the same area including [12–14]. The vegetation analysis comprised the calculation of:

**Density** (number of stems/ha of mature trees, poles, and saplings).

**Relative density** (Density of one species compared with density of all species, \(RD = \frac{Di}{D}\), where \(RD\) = relative density, \(Di\) = density of species i, \(D\) = Density of all species.

**Frequency** (number of plots in which particular species were found)

**Relative Frequency** (Frequency of one species compared with frequency of all species, \(RF = \frac{Fi}{F}\), where \(RF\) = frequency relative, \(Fi\) = frequency of species i, \(F\) = frequency of all species.

**Dominance** (number of individuals of a particular species (i) as a proportion of the basal area of individuals of all species, \(D = \frac{Ni}{N}\), where \(Ni\) = basal area of species i, \(N\) = basal area of all species.

**Relative Dominance** (Dominance of one species compared with dominance of all species, \(RD = \frac{Di}{D}\), where \(RD\) = Relative Dominance, \(Di\) = dominance of species i, \(D\) = Dominance of all species.

**Shannon Diversity Index** (H’) (calculated as \(H' = \sum_{i=1}^{n} pi \ln pi \)) where: \(pi\) = number of individuals of species i divided by the number of individuals of all species; and \(n\) is the number of different species.

**Importance Value** (IV) (calculated by summing the relative density, relative frequency and relative dominance).

To find out the association between Pangi trees and other plants used: Ochiai index [15].

\[
OI = \frac{a}{\sqrt{a + b}\sqrt{a + b}}
\]

where: \(a\) = number of plots where both species A and B are found; \(b\) = number of plots where species A is found but not:species B; \(c\) = number of plots where species B is found but not: species A; Association occurs in the range of values 0 – 1.

3. Results and discussion

3.1. Pangi fruit production
The results of data analysis in Appendix 1 show that different altitudes have a significant effect on the production of pangi fruit. The results of the Tukeys difference test at the level of 0.05, showed that the altitude of 800-850 m asl gave higher yields of pangi fruit and was significantly different with elevation > 1,000 m asl, but not significantly different with elevation < 600 m asl. For more details, it is presented in Figure 1.
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Figure 2. Pangi fruit production at three different altitudes.

Plant fruit production is indirectly influenced by altitude and aspect because of their relationship with the photosynthesis process of plants. The east-facing slope receives more morning sunlight than the west-facing slope, so that the photosynthesis process of plants on the east-facing slope is better. Thus, the fruit production of plants located on slopes facing east is higher than those on slopes facing west. This is in line with the results of research by [16] on ebony plants that the physiological characteristics of the leaves were influenced by their position in the tree crown and differences in altitude. It is the same with the altitude factor that the higher the altitude, the more growth limiting factors are found. The higher the altitude, the slower the decomposition of soil organic matter, but soil erosion is usually greater. Likewise with the temperature, the higher the altitude, the lower the air temperature. This is slightly different from the results of [17] that the net ecosystem productivity (NEP) of slopes facing southwest is higher than slopes facing northeast, as well as soil respiration (SR) is higher on slopes southwest. Soil organic carbon content decreases significantly with decreasing altitude. The net primary productivity (NPP) and NEP have not yet been determined to be related to altitude in their research.

3.2. Basal Area of Pangi trees

The results of data analysis in Appendix 2 show that different altitudes have a significant effect on the Pangi basal area. The results of the Tukeys test at the level of 0.05 showed that the altitude of 800-850 m asl gave a larger Pangi basal area and significantly different with elevation >1,000 m asl but not significantly different with elevation < 600 m asl. For more details, it is presented in Table 1.

| Altitude (m MSL) | Basal area (cm²) | Tukeys test 0.05 |
|------------------|------------------|-----------------|
| >1000            | 233.33           | a               |
| <600             | 346.67           | a b             |
| 800-850          | 462.14           | b               |
Table 1 explains that the basal area of the Pangi plant at an altitude of 800 – 850 m MSL was larger and significantly different with an altitude >1,000 m MSL. This is due to the fact that at altitude >1,000 m MSL the temperature factor is lower as a consequence of increasing altitude. According to the theory that for every 100 m increase in altitude above sea level, the air temperature will decrease by 0.64 °C.

3.3. Average height (m) of Pangi Tree

The results showed that different altitudes had no significant effect on the average height of the pangi trees, however there was a tendency that the higher the altitude, the smaller the growth of tree height. For more details can be seen in Figure 3.

Figure 3 shows that the difference in plant height growth at three different altitudes was not significantly different. This may be due to the fact that the three altitudes studied are still within the growing range of the pangi plant or that the pangi plant can grow in a wide range of altitudes, so the average height of the pangi plant is relatively the same. This is in line with the statement [2] that Pangi plants are found growing both in primary and secondary forests, on alluvial, podzolic soils, rocky or clay soils that are poor in nutrients and at an altitude of 10 – 1000m MSL. Even in some areas in South Sulawesi, such as Toraja, Soppeng and Bantaeng, the community has cultivated it in the form of mixed community forests and agroforestry. Pangi tree is an evergreen plant, found growing in lowland forests, but is still found up to an altitude of 1200 m above sea level. The tree is 25 m high, but can reach 60 m with a diameter of 50 cm, but can reach 120 cm and has buttresses [3].

3.4. Average diameter of Pangi Trees

The results of data analysis in Appendix 3 show that different altitudes have a significant effect on the average diameter of the pangi trees. The results of the Tukey’s test at a level of 0.05 showed that an altitude of 800-850 m asl resulted in a larger average diameter of the pangi tree and significantly different with elevation >1,000 m asl but not significantly different with elevation <600 m asl. For more details, it is presented in Table 2.
Table 2. Average diameter of Pangi trees at three different altitudes.

| Altitude (m MSL) | Average diameter (cm) | Tukeys test 0.05 |
|------------------|-----------------------|------------------|
| >1000            | 36.30                 | a                |
| <600             | 36.90                 | a b              |
| 800-850          | 41.80                 | b                |

At an altitude of 800 – 850 m MSL, the diameter growth of the pangi plant was greater than at an altitude >1,000 m MSL. This is due to the fact that each plant species has the desired altitude range for its growth, although the pangi plant can still grow at an altitude of 1,000 m MSL. However, optimal diameter growth must be supported by optimal environmental conditions, including altitude. As stated by [18]. and Anonim (Plant Resources of South East Asia) that the diameter of the pangi plant can reach 100 cm and a height of 40 m. This is in line with the statement (2000) that pangi plants grow well and generally spread naturally in lowland areas and the banks of rivers or waterways, however, they can still grow up to an altitude of 1200 m MSL.

3.5. Average Tree Density of All Plant Species
The results of data analysis in Appendix 4 show that different altitudes have no significant effect on tree density of all plant species. The results of the Tukeys different test show that an altitude of 800-850 m asl tends to produce a higher density of trees of all types of plants compared to an altitude > 1,000 m asl and an elevation of < 600 m asl. For more details, it is presented in Figure 4.

![Figure 4. Density of all tree species at three different altitudes](image)

3.6. Average Density of Pangi Trees
The results of data analysis in Appendix 5 show that different altitudes have a significant effect on the average density of pangi trees. The results of the Tukeys difference test at the test level of 0.05 showed that at an elevation of 800-850 m asl gave an average density of Pangi trees which was more and significantly different from the average density of Pangi trees at an altitude > 1,000 m asl and at an altitude < 600 m asl. For more details, it is presented in Figure 5.
3.7. Diversity of Agroforestry System

The results showed that there were 37 plant species and 25 families found at the research site. However, what is shown in Table 3 is only 9 plant species that have an important value index (IVI) greater than 10%. The plant species that had the highest IVI was Pangi with 82.31 and followed by coffee, cacao, and mountain pine.

**Figure 5.** Density of Pangi trees at three different altitudes.

Pangi plants that were the object of research were plants grown by the community, although there were also plants that grow naturally as a result of natural regeneration (fruit that falls and was not picked up by farmers and was allowed to grow and be maintained to increase the population or density of the Pangi tree). Thus, the density of the Pangi tree was closely related to the site factor.

**Table 3.** Importance value and Shannon Diversity Index ($H'$) for plant species in Tanatoraja Regency.

| Local name | Latin Name                  | Family    | Relative density(%) | Relative Frequency (%) | Relative dominance (%) | Importance value (IVI) | $H'$ |
|------------|-----------------------------|-----------|---------------------|-----------------------|------------------------|------------------------|------|
| Aren       | Arenga pinnata              | Areceae   | 3.23                | 4.17                  | 6.94                   | 14.34                  | 0.15 |
| Cemara gunung | Casuarina junghuniana Theobroma cacao | Casuarinaceae | 10.03              | 8.68                  | 5.14                   | 23.86                  | 0.20 |
| Kakao      | Theobroma cacao             | Malvaceae | 15.96               | 9.03                  | 2.29                   | 27.27                  | 0.22 |
| Kopi       | Coffea spp.                 | Rubiaceae | 18.59               | 9.72                  | 2.00                   | 30.31                  | 0.23 |
| Mahoni     | Swietenia sp                | Meliaceae | 2.69                | 4.51                  | 4.29                   | 11.49                  | 0.13 |
| Pangi      | Pangium edule               | Achariaceae | 19.53              | 10.42                 | 52.37                  | 82.31                  | 0.35 |
| Pisang     | Musa paradisiaca            | Musaceae  | 5.99                | 5.90                  | 0.29                   | 12.18                  | 0.13 |
| Sengon     | Paraserianthes falcataria   | Fabaceae  | 3.97                | 6.60                  | 5.44                   | 16.01                  | 0.16 |
The number of plant species found in this study was less when compared to the results of research by [18] on the rattan agroforestry system at Tumbang Runen village the Katingan District, Central Kalimantan Province which found as many as 101 plant species and 80 species (79%) of which were tree species.

Pangi plants have a higher IVI compared to other plants due to environmental factors in the research location that are suitable for the growth of the Pangi plant. The research location has air temperature between 20 – 28°C, air humidity between 82 – 86%, and rainfall 2000 – 3500 mm/year (Nanggala and Pangli climate stations). A type of plant can grow and spread well if the environmental factors match what it needs. The location of this study is relatively the same as the habitat of the Pangi plant at the research location of [2]) that biophysical information of the Pangium vegetation were 24-30°C daily temperature, 50-80% humidity, 10-65% slope, and 15-306 m altitude and soil is Latosol with pH 5.5-6.5.

Table 3 also illustrates that the diversity of species (H') in the research location is 2.64 which is classified as moderate. The diversity of species found in the medium category is caused by the limited opportunities for farmers to choose and planted their gardens with various types of plants due to environmental factors such as altitude. The research area is a mountainous area that has many growth limiting factors such as altitude, slope, and the area of land owned by farmers is quite narrow. The number of plant species and the diversity of plant species found in the agroforestry system is not only determined by the area of land, and physical environmental factors such as altitude, rainfall, soil conditions but is also mostly determined by socio-economic factors of the agroforestry land owner. However, the results of the study [19] found that in a narrow agroforestry area, more plant species were found than in a wider agroforestry area. Farmers choose plants according to their needs and the number of results obtained, so the types of plants that are more expensive, high production are always a consideration for farmers in choosing the type of plants, so that the types of plants are relatively the same in the same village.

### 3.8. Association of Pangi Plants with Other Species

A plant species can be known to be closely associated with other species by looking at its association index. The results showed that the Ochiai index (association of pangi plants with other plants) ranged from 0.97 – 0.18. For more details can be seen in Table 4.

#### Table 4. Association index of pangi with 36 other plant species.

| Local name     | Latin name                                | Family name | Association index |
|---------------|-------------------------------------------|-------------|------------------|
| Pangi         | Pangium edule                             | Achariaceae | 0.97             |
| Kopi robusta  | Coffea robusta                            | Rubiaceae   | 0.95             |
| Kakao         | Theobroma cacao                           | Malvaceae   | 0.91             |
| Cemara gunung | Casuarina junghuhniana                    | Casuarinaceae | 0.91         |
| Ubi jalar     | Ipomea batatas)                           | Convolvolaceae | 0.91       |
| Pisang        | Musa paradisiaca                          | Musaceae    | 0.84             |
| Mayana        | Solenostemon scutellarioides             | Lamiaceae   | 0.82             |
| Suren         | Toona sureni                              | Meliaceae   | 0.80             |
| Sengon        | Paraserianthes falcata                      | Fabaceae    | 0.80             |
| Nangka        | Artocarpus integra                        | Moraceae    | 0.74             |
Table 10 shows that Pangi plants are very closely associated with several other plant species, indicated by the Ochiai index approaching the value of one and several plant species that are not closely associated with the Ochiai index away from the value of one. Mountain cypress trees (*Casuarina junghuniana*) and cash crops (*Theobroma cacao*) show a close relationship with pangi because the Ochiai index is close to one, which is 0.91 and 0.97, respectively. This is very reasonable because these two plant species are plants that grow and spread well in mountainous areas such as Tanatoraja. The results of this study differ from the results of research [2] which found that the Pangi species was closely associated with *Pterocymbium javanicum* in Meru Betiri National Park with an Ochiai index of 0.69. In addition to these two plant species, they are ecologically suitable for developing in mountainous areas, these two plants are also the mainstay of the Toraja people, so there is an element of human intervention in the plant adaptation process. Coffee plants are always present in every community agroforestry garden because it is a source of daily income. Likewise, mountain cypress plants are always present in their agroforestry land because it is very important in the construction of Tongkonan traditional houses. This is different from the clove and Sendana species, these two types of plants are not ecologically suitable to be developed in mountainous areas such as Tanatoraja, even though these two plants are of high value. The Sendana plant, although its wood is very good, is classified as durability class 2 and strength class 2 [20], but for the people of Tanatoraja it is considered to have a "mystic" value, so it is rarely planted.
or grown on agroforestry land, but is always planted in front of the Tongkonan traditional house which have sacred and mystical values.

4. Conclusion
The highest fruit productivity of the pangi plant was at an altitude of 800 – 850 m asl, tree density, basal area and diameter of the pangi tree were significantly different at each different altitude, but the number of plant species and the diversity of plant species at each altitude was relatively the same, namely the medium category. Plant species that have a high association index for pangi was coffee, cacao, and mountain cypress, which are 0.97, 0.95, and 0.91 respectively. Therefore, pangi crops were not recommended to be developed at an altitude above 850 m above sea level but can be planted together with mountain cypress, coffee and cocoa.

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