Current status of taro (*Colocasia esculenta*) utilization as local food diversification toward climate resilience in Indonesia

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Abstract. Indonesia is a tropical country that experiences the impact of climate change. The utilization of taro as an amphibian crop might sustain the food availability for the most vulnerable farmers against the negative impact of climate change. The study aims to evaluate the current status of taro utilization and production as local food concerning food diversification, sustainable agriculture, and climate change issues. Data were obtained from a focus group discussion with primary stakeholders of the taro value chain and literature review. Results show that taro is an important secondary food in some regions with three main uses as local consumption, local trading, and export. Prominent taro consumers existed in West Papua, Papua, Maluku, and Central Sulawesi Provinces with consumption rates 10.6, 5.3, 2.2, and 2.0 kg/capita/year, respectively. Taro was intensively cultivated in Banten, West Java, and South Sulawesi provinces, for fresh and processed products. The respondents agree with taro as a prospective adaptive crop to climate change of both drought and excess precipitation. There are some issues in the biodiversity conservation, crop improvement, link-match industry, and stakeholder capacity building for competitive, quality, quantity, and sustainable production, as future works in the taro value chain in Indonesia.

1. Introduction
The first world climate conference in 1979 designated that the climate change issue has become a worldwide concern through many disciplines including agriculture, water resources, fisheries, energy, medicine, environment, biology, sociology, and economics [1]. Climate change covers issues such as increased temperatures, biodiversity reduction, wind patterns, droughts, excess precipitation, and heat waves [2].

On agricultural production, the negative impact of climate change is a great concern as described by many authors. By 2080, global agricultural productivity is projected to decrease 3-16% with the developing countries losing 10-25% and the rich country’s loss about 6% [3]. Indonesia as the biggest archipelago country in tropical Asia, is predicted to have the worst climate change [4]. In the last ten...
years, climate change is responsible for changing seasons and rainfall patterns in Indonesia, which have affected agricultural commodities production significantly [5][6][7].

On the other hand, in Indonesia as an inhabitant of 269 million people, about 90% rely on rice as staple food [8]. Although there is a tendency in declining rice consumption, the annual consumption rate is still high, about 100-114.3 kg/cap [9][10]. Under the national self-sufficiency program, to provide 30.7 million tons of rice requires harvesting rice fields of about 15.8 million ha [11]. The rice field is supported by a full irrigated field (45.3%), semi-irrigated (46.4%), and rain-fed (7.9%) [12]. Consequently, climate change is a sensitive issue in rice production. The delay in the wet season and a temperature increase of 2.5 °C are projected to decrease rice yields and farm-level net revenue by 9-25% [13]. Therefore, the Indonesian government promotes food diversification and stabilizing food security through promoting local food, increasing local community access to local food, and climate-adaptive crops [10]. To sustain such a food system, it's recommended to develop crops based on natural resources [14].

Taro or talas in Indonesian, refer to the general term of *Colocasia* sp. and *Xanthosoma* sp., are tuber crops from Araceae members. In Indonesia, various taro genotypes are popular that grow well in an area such as home garden, farmer field, riverbank, and swampy area [15]. Nevertheless, taro is a minor crop and the recent status of taro utilization is still unknown, despite it being used as a staple food like other countries in southeastern Asia. The study aims to evaluate the current status of taro utilization and production as local food concerning food diversification, sustainable agriculture, and climate change issues.

2. Methodology
This study was conducted in January–March 2021. The primary data were obtained from a focus group discussion on February 16, 2021, involving stakeholders related to taro utilization and conservation. The focus group discussion included farmers, the Food Security Agency of Ministry of Agriculture, extension service officer (Bogor Regency, Pandeglang Regency), universities (agronomist, horticulturist, agribusiness), a research institution (Indonesian Center for Agriculture Biotechnology and Genetic Resource Research and Development), non-government organization, trader, exporter, taro processing industry (post-harvest, food industries), and policy maker. In total, 75 persons were involved in the focus group discussion. Issues raised during the activity were diversification program, taro genetic conservation, production, farmer’s problems, supply chain, trading, export, and processing industries.

The additional data were collected from works of literature review available related to Indonesian taro utilization and production. The review covered the publication dated 2010-2020. The flow of literature review follows [16], named as scoping review. According to [17], scoping review is literature research to map a particular topic and identify the most important information, including concepts, evidence in practice, gaps, and policymakers. The goal of the scoping review was to evaluate the current status of utilization, conservation effort, the nature of production, and extent in the processing industry. Briefly, the scoping review was mainly based on publication available in GARUDA as the primary portal of published Indonesian journals and Google searching platform. The keywords included: "utilization", "problem", "prospect", "industry", "post-harvest", "export", "trading", "cultivation", "production", "food diversification", "climate change", and "food security" in combination with "taro" (talas-Indonesian). Published materials were screened initially based on the title for rapid evaluation. The article with a related title was then downloaded for secondary evaluation based on the abstract. Finally, only articles that match the scope of research were considered.

3. Results and Discussion
3.1. Taro research and distribution
The research and distribution characteristics in Garuda portal articles were described and summarized (Table 1). Taro as a general topic of research discovered in 360 articles that searched by abstract category date from 1983 to 2021 (38 years). It means 9.47 articles were published per year. Nearly equal to the result of a base title search, which yielded 352 articles from 1987 to 2021 (34 years) or 10.35 articles
per year. The majority of the articles were in agriculture, with tuber, leaves, and cultivation being the main concern topics. Taro marketing, industry, processing, utilization, and production were other topics that were of a researcher's interest. The fieldwork about micropropagation, breeding, biotechnology, export, post-harvest, and conservation was still poor. Worse, no research into the relationship between taro development and climate change has been done.

| Table 1. Scopes of literature included in the review |
|---------------------------------------------|---------------------------------------------|
| Aspect                                      | By abstract                        | By title                          |
| Taro (in general)                          | N                                    | N                                    |
|                                            | Percentage                          | Percentage                        |
| Agriculture                                | 251                                  | 104                                 |
|                                            | 69.72                                | 29.55                               |
| Seed                                       | 17                                   | 3                                   |
|                                            | 4.72                                 | 0.85                                |
| Tuber                                      | 113                                  | 57                                  |
|                                            | 31.39                                | 16.19                               |
| Leaves                                     | 64                                   | 29                                  |
|                                            | 17.78                                | 8.24                                |
| Pest                                       | 5                                    | 1                                   |
|                                            | 1.39                                 | 0.28                                |
| Disease                                    | 11                                   | 3                                   |
|                                            | 3.06                                 | 0.85                                |
| Propagation                                | 9                                    | 2                                   |
|                                            | 2.50                                 | 0.57                                |
| Micropropagation                           | 2                                    | 4                                   |
|                                            | 0.56                                 | 1.14                                |
| Breeding                                   | 2                                    | 0                                   |
| Cultivation                                | 26                                   | 7                                   |
|                                            | 7.22                                 | 1.99                                |
| Biotechnology                              | 2                                    | 2                                   |
|                                            | 0.56                                 | 0.57                                |
| Economic                                   | 29                                   | 2                                   |
|                                            | 8.06                                 | 0.57                                |
| Export                                     | 2                                    | 0                                   |
|                                            | 0.56                                 | 0                                   |
| Trading                                    | 3                                    | 0                                   |
|                                            | 0.83                                 | 0                                   |
| Import                                     | 3                                    | 0                                   |
|                                            | 0.83                                 | 0                                   |
| Marketing                                  | 21                                   | 2                                   |
|                                            | 5.83                                 | 0.57                                |
| Food and processing                        | 63                                   | 6                                   |
|                                            | 17.50                                | 1.7                                 |
| Industry                                   | 25                                   | 0                                   |
|                                            | 6.94                                 | 0                                   |
| Post-harvest                               | 2                                    | 2                                   |
|                                            | 0.56                                 | 0.57                                |
| Processing                                 | 36                                   | 4                                   |
|                                            | 10.00                                | 1.14                                |
| Sustainability and climate change          | 32                                   | 19                                  |
|                                            | 8.89                                 | 5.40                                |
| Climate change                             | 0                                    | 0                                   |
|                                            | 0                                    | 0                                   |
| Exploration                                | 5                                    | 2                                   |
|                                            | 1.39                                 | 0.57                                |
| Conservation                               | 2                                    | 3                                   |
|                                            | 0.56                                 | 0.85                                |
| Characterization                           | 12                                   | 12                                  |
|                                            | 3.33                                 | 3.42                                |
| Diversity                                  | 13                                   | 2                                   |
|                                            | 3.61                                 | 0.57                                |
| Development                                | 89                                   | 34                                  |
|                                            | 24.72                                | 9.66                                |
| Utilization                                | 20                                   | 17                                  |
|                                            | 5.56                                 | 4.83                                |
| Prospect                                   | 4                                    | 1                                   |
|                                            | 1.11                                 | 0.28                                |
| Problems and obstacles                     | 5                                    | 0                                   |
|                                            | 1.39                                 | 0                                   |
| Production                                 | 46                                   | 16                                  |
|                                            | 12.78                                | 4.55                                |
| Food diversification                       | 11                                   | 0                                   |
|                                            | 3.06                                 | 0                                   |
| Food security                              | 3                                    | 0                                   |
|                                            | 0.83                                 | 0                                   |

Note: by abstract percentage = N/a x 100%, by title percentage = N/b x 100%
3.2. Policy and implementation of the food diversification program

Under the business scenario, as usual, Indonesian demand for rice would be 36.2 million tons in 2025, and 40.7 million tons in 2045. In this case, the annual rice consumption scenario is declined by 0.7%; thus by 2024, it will be 91.2 kg/capita. The high dependency on rice resulted in the rice as a sensitive commodity from a historical perspective, economy, and politics. Therefore, the role of the Food Security Agency of The Ministry of Agriculture (Badan Ketahanan Pangan-BKP) that was established through Presidential Decree in 1999, is very important.

The BKP is the only coordinator for the food diversification program in Indonesia. This institution was mandated to evaluate and report the food availability, reduce food insecurity, stabilize the access and distribution of food, diversify food consumption, and increase food security (www.bkp.pertanian.go.id). In the field of diverse programs and community food security, the BKP launched five activities, namely: 1) Equitable prosperity and handling of poverty and food insecurity, 2) Price stability and food supply, 3) Increase of food diversification; 4) Supervision of food safety and quality and 5) Analysis, studies, and policy. The main strategy of the food diversification program is improving food diet by utilizing local food with better nutritional quality [18].

Promoting local food is reasonable because almost all Indonesian regions have local staple food [19]. For example, Timorese people in Nusa Tenggara Timur province, use staple food such as corn, cassava, sweet potato, and mung bean [20], Papuanese in West Papua province use seven local food, i.e., sago, cassava, sweet potato, banana, corn, taro, and breadfruit [21], and sago also found in Maluku as local food [22]. The small community of Malomahu, in Pulubala District Gorontalo Province [23], Madura community in Pamukian District in Madura island [24] consume corn as a staple food, not rice. Ethnic Tolaki in Kolaka District-South East Sulawesi Province uses sago as a staple food, and symbol of prosperity. By replacing rice with local food, the Indonesian government targets to reduce rice consumption by 2 kg/capita per annum [10]. According to [14], to replace rice consumption by 2 kg/capita there is a need to increase tuber consumption by 10 kg/capita or corn consumption by 5 kg/capita. Nevertheless, promoting diversification is not easy. Therefore, the government develops long-term programs related to non-rice food contribution to the diet. The consumption of non-cereal food promotion included cassava, sago, potatoes, bananas, and taro (Table 2).

Table 2. Target contribution of a local source of carbohydrate and designed annual consumption rate increment, and production status in Indonesia

| Local food | Consumption by 2020-2024* | Production status 2018** |
|------------|--------------------------|-------------------------|
|            | Contribution (%) | Consumption rate  (kg/capita/year) | Production (Million ton) | Growth*** (%) |
| Cassava    | 40                     | 1.90                    | 25.54                   | 1.34         |
| Corn       | 10                     | 0.21                    | 20.11                   | 0.86         |
| Sago       | 20                     | 0.40                    | 0.43                    | 1.37         |
| Potato     | 10                     | 0.83                    | 1.22                    | 0.91         |
| Banana     | 10                     | 0.46                    | 7.18                    | 1.05         |
| Taro       | 10                     | 0.62                    | not available           | not available |

Source: *BKP 2020; ** Fresh products (Data Center of Agriculture Ministry of Republic Indonesia 2020); *** average 2015-2018 relative to 2014

During focus group discussion (FGD) it was noted that in the last about 5 years the production of primary local food tended to increase, but taro production has not been well recorded (Table 2). This illustrates that taro was once regarded as a minor product not only by the majority of Indonesians but also by the government. Taro cultivation will require greater attention in the future, as this commodity has a lot of potential as alternative food and a source of farmers' income. Furthermore, taro has gained the interest of various entities as an export item, especially in the last three years.

The audience in the FGD suggested promoting consumption of taro and other non-rice carbohydrates through 1) increase production through application of cultivation technology, superior seed utilize and farming extensification, 2) increase community access to local food through adequate availability and
affordable price, 3) to maintain the supply and price, 4) to cooperate with smallholder industry and private sector applicant post-harvest and processing technology and develop storage system, 5) to educate public and promote intensively in various media (digital, non-digital, formal and non-formal) to pursue the people to change their mindset. For these efforts, the BKP released a public jargon "Full doesn't mean rice" and "be smart eat smart" [10].

3.3. Taro consumption and utilization

In 2019, the taro consumption rate was 0.6 kg/capita and would be increased by 0.1 kg/capita/year without government intervention, and the consumption would be increased 0.6 kg/capita/year to achieve 3.7 kg/capita in 2024 by special government program [10]. The intervention mainly focused on some regions where prominent production and consumption existed mainly in 14 out of 34 provinces in Indonesia (Figure 1). The 14 provinces were: West Papua, Papua, Maluku, North Maluku, Central Sulawesi, North Sulawesi, East Nusa Tenggara, West Nusa Tenggara, Bali, West Kalimantan, Central Kalimantan, East Java, Central Java and West Java.

Taro was a popular food in West Papua Province (10.6 kg/capita/year), followed by Papua Province (5.3 kg/capita/year), Maluku Province (2.2 kg/capita/year), and Central Sulawesi (2 kg/capita/year) [10]. Taro as a staple food is found in Papua Province [25] and the locality utilizes it in another province as a snack or vegetable [26]. Unfortunately, detail of consumption and production statistics on taro is still lacking.

In some districts, taro is obtained traditionally by self-sufficient with minimum cultivation. Natives of the Kaimana District of West Papua Province grow mixed taro and other crops in the yard of farm households [27]. Tuber crops are very important in a household in East Nusa Tenggara who have limited stock of rice and corn for daily needs, especially during the dry season, and it is obtained either from the farmer field or forest [28]. Traditional communities in Western Seram, Maluku Province, still maintain a diet with mixed staple food especially cassava, sweet potato, taro, yams, and these menus must be provided in traditional events [29]. Taro as a staple food is also used by an indigenous community in Sigi District – Central Sulawesi and the agricultural land is managed wisely which is not planted in the same area for restoring the fertility period of the land [30].

Concerning what is known from Banten and South Sulawesi, the target location for increasing taro consumption does not appear to be the place where taro is produced and processed intensively (Fig 1). Even though taro production, processing, and marketing have advanced in West Java, Banten, and South Sulawesi, consumption remains low due to the development's emphasis on export, not the purpose of local need consumption. Sustainable consumption and production are integrated with economic elements and social aspects that are driven by consumption and production patterns prevailing in society [31]. Thus, the effort to raise taro consumption in West Java would be easier than other provinces in the supply chain because taro has become a valuable commodity; however, here social aspects, especially education, promotion, and socialization, must be hardly improved. Contradictory in Papua, Maluku, and Nusa Tenggara, although the people are more enthusiastic about taro consumption, the cultivation and processing technology are very basic, resulting in low economic value [28][32][33]. Consequently, government intervention is provided to enrich the farming and processing technology to accelerate target achievement. Food technology applications have changed the edible raw material to be more palatable, available, affordable, and sustainable [34]. Programs for these purposes have already been launched for communities in several regions in Indonesia [35][36]; and similar activities should be maintained, expanded, and encouraged by achieving economic value with better markets and purchases.
Figure 1. Annual taro consumption in 2019 of 34 provinces in Indonesia. Source: BKP (2020)

3.4. Cultivated variety and species

There is a wide variety and species of the taro that existed throughout the Indonesian archipelago, and the "taro" terminology refers to *Colocasia* sp. and *Xanthosoma* sp. Farmers and consumers are still confused about the scientific name of the taro, although some ethnicities have a particular name for different or similar species. Javanese refers to Belitung, Kimpul, and Mbothe for *Xanthosoma* group, Talas or Tales for *Colocasia* group, and Center or Senthe for Alocasia and other gigantic taros groups. In general, genetic distribution and uses of general taro species spread over islands at different agro-ecologies (Table 3).

In general, taro that is commonly consumed and cultivated by Indonesian people are species that are included in the *Colocasia* and *Xanthosoma* groups. Some species belonging to the Caladium and Alocasia groups are oftentimes performing as ornamental plants due to the beauty of the leaf lamina. These two groups are also used for pesticides and traditional medicines. Related to these uses, it is still fundamental to do a more in-depth study about the active compounds that have medicinal properties or poisonous agents for pests and diseases.

Recently, some taro species were cultivated intensively in some areas in several provinces, e.g., Provinces of Banten, West Java, and South Sulawesi. The species were considered to have high economic values as fresh consumption and processing taro. The most prominent species were: Beneng or elephant ear (*Xanthosoma undipes*), cultivar Pratama (*Colocasia esculenta* var. esculenta), and
Japanese taro or Satoimo (*Colocasia esculenta* var antiquorum). These species had specific characteristics in growth appearance, tuber shape and size, taste, and nutrition composition. Therefore, they had a different purpose in the cultivation. The tuber of Beneng variety is used as a flour industry raw material that has high demand in the domestic and foreign markets (Canada, Netherland, Australia, Turkey). Pratama and Satoimo market in the country and abroad that sell fresh and frozen form, but Satoimo is exported specifically to Japan and Korea. Taro Mentega is a specific location of taro cultivars and legendary in Bogor, so it's better known as Bogor's Taro.

| No | Species | Local name | Distribution (Province) | Uses | Reference |
|----|---------|------------|-------------------------|------|-----------|
| 1  | *Colocasia esculenta* | Keladi nyatoh, keladi rakit, Lompong pari, talas hitam, lumbu kobis, Bentul putih | Bangka, Belitung, Central Java, East Java | Snack and vegetables, Snack and vegetables, Snack and vegetables | [37], [38], [39] |
|    |         | Talas enggano, talas melati, talas cimpul, Talas semir, talas bogor, talas laahun indung, Talas safira, talas bite, talas upe, Hekhei khleumang, Hekhei hasai, embewi, Ifan berik, nomo Keladi mai, keladi kuning | Bengkulu, West Java, South Sulawesi | Snack and vegetables, Snack, vegetables | [40], [41], [42], [43] |
|    |         | Hekhei kimpul hijau/mbote | Maluku | Staple food | [44] |
| 2  | *Caladium bicolor* | Keladi belau | East Kalimantan | Traditional medicine, ornamental | [45] |
| 3  | *Alocasia indica* | Keladi birah | East Kalimantan | Pesticide | [46] |
| 4  | *Xanthosoma undipes* | Talas beneng | Banten | Taro flour industry | [47] |
| 5  | *Xanthosoma sagittifolium* | Keladi picit, keladi johor, Kimpul hijau/mbote | Maluku, East Java | Staple food, Snack and feed | [44], [39] |

3.5. Genetic conservation

Making taro as an alternative carbohydrate source is supported by Indonesia's natural wealth, which provides hundreds of edible taro species but has yet to be exploited. The challenge of the Indonesian government is to strike a balance between exploitation and conservation to ensure sustainability. Germplasm collection is the first and important step in a breeding program that must be completed, followed by genotype selection to meet the breeders' requirements. The greater the diversity of germplasm, the more likely it is to find the appropriate genotype.

The Ministry of Agriculture has the mandate of responsibility for plant biodiversity management and protection through The Center for Agriculture Biotechnology and Genetic Resource Research and Development (BB Biogen). For the last five years, BB Biogen has explored tuber crops such as taro plants that preserve in the gene bank. A total of 265 edible taro accessions have been characterized morphologically and molecularly; it is the early stage of taro breeding and the more advanced stages are still a rare occurrence.
So far, the taro cultivar which is widely cultivated and in high demand such as Beneng, Pratama, and Bogor's is achieved through the domestication and characterization process of wild types from forests, even Beneng approaches like a weed [47]. However, to ensure long-term viability taro needs to be improved, particularly in terms of plant adaptability to abiotic and biotic stress caused by climate change. Last experience has shown that the advancement of Bogor's taro cultivar has been obstructed by serious disease outbreaks, and it is now only found in a small population. In Samoa, the taro leaf blight disease has been caused by nearly destroying the crop [48]. It is important to study ethnobotany and on-farm conservation models in taro in Indonesia.

4. Conclusion

The findings of research and publications reflect how much attention has been paid to Indonesia's taro development initiatives. The agriculture aspect has received more attention than other aspects in the previous three decades. This plant is intensively cultivated in some regions in Indonesia for the raw material of flour industry needs and exports. Taro is a staple food for some societies, particularly in eastern Indonesia, but it is primarily used as a rice substitute when rice is limited. To reduce rice consumption and strengthen food security, the Indonesian government has implemented a food diversification program based on local commodities. Taro is a promising product for the program's success since it can adapt to various agro climatic conditions, is easy to find throughout Indonesia's archipelago, has a high genetic diversity that is needed for character improvement, and Indonesia's people have long been familiar with taro-based food. As future work in the taro value chain in Indonesia, there are certain challenges in terms of biodiversity conservation, crop enhancement, link-match industry, and stakeholder capacity building for competitive, quality, quantity, and sustainable production.

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