Economic Valuation of Nipa Palm (*Nypa fruticans* Wurmb.) Sap as Bioethanol Material

Imawan Wahyu Hidayat

1Cibodas Botanical Garden, Indonesian Institute of Sciences (LIPI), P.O. Box 19 SDL, Sindanglaya-Cipanas, Cianjur 43253, West Java, Indonesia

Email: imawan.wahyu.hidayat@lipi.go.id

Abstract. Nipa palm (*Nypa fruticans* Wurmb.) widely recognized as one of the biological resources with various aspect of utilization. Nipa palm sap can be processed into bioethanol. Bioethanol also has a quite high selling price, especially for the fulfilment of energy and for fossil fuels substitution. The main purpose of the study was to evaluate the economic value of nipa sap for further processed into bioethanol, in order to improve the income and job opportunity of coastal households. This research was conducted at Sungasang, South Sumatera with focusing on nipa palm sap further processing into bioethanol and its impact on increasing household income. This research was statistically testing the relationship between potential production of bioethanol, average revenue and labour recruitment. Based on the 2013 data, potential production of bioethanol was capable to contribute of nett income about IDR 507,940 to 3,503,280 ha\(^{-1}\) month\(^{-1}\) or IDR 6,095,274 to 42,039,360 ha\(^{-1}\) year\(^{-1}\). Therefore each hectare of nipa palm can generate labour recruitment up to 3.7 person ha\(^{-1}\). This assessment was expected to provide a better description of the importance of local biological resources utilization of the nipa palm, in order to improve community welfare and the efforts of biodiversity conservation on a local scale.

1. Introduction
The total primary energy share of around 78.9% was produced from fossil fuel that precludes nuclear, hydro, biofuel and other energy sources [1]. For comparison, in 1973, fossil fuel percentage of the total primary energy share was 86.7%. At the global level, 57.7% of the energy is accounted for transportation system [2]. Petroleum-based fuels lead to environmental pollution, which results in global warming, health hazards, and ecological imbalances [3]. The shift towards sustainable and environmentally friendly energy sources has generated significant interest in developing biofuel production from plant biomass [4].

In 2013, Indonesian oil consumption reached 1.61 million barrels per day, yet the country is "only" capable to produce as much as 874.79 thousand barrels of crude oil per day [1]. The dependence of the energy needs on fossil fuels of Indonesia is also seen in the proportion of the total fossil fuel consumption by 73% compared to other sources, such as biomass and other renewable sources, by 27% in 2012. This certainly implies concerns for policymakers to encourage explorations of alternatives that would be viable and regenerative to attain sustainability. Renewable energy opened up prospects for appropriate resource conservation and an eco-friendly solution directed to energy security [5].
Indonesia with its high biodiversity resources has high potentials for developing new and renewable energy derived from plants. Bioethanol derived from nipa palm (*Nypa fruticans* Wurmb.) sap is one of them. Ethanol which is produced by nipa sap is better than sugarcane, even other sugar sources such as cassava, coconut and potato [6]. Nipa sap is a potential material to be processed into bioethanol [7][8]. Bioethanol is one of the sources of renewable energy which can replace or a mixture of fossil fuels, by its widely used in beverages, cosmetics, in the health field as an antiseptic substance, a solvent, as well as an industrial raw material. The total nipa sap chemical composition is 19.5 wt%, mainly consisting of sucrose, glucose and fructose [7]. The potential of nipa sap that can be generated is ranged from 0.4 to 1.2 L d⁻¹ per palm [8]. *N. fruticans*, an underutilized palm, was assessed recently for bioethanol yield by several authors. Tamunaidu et al. [8] conducted a detailed study for ethanol production from *N. fruticans*. If a sap yield of 0.5–1.0 L palm⁻¹ day⁻¹ is assumed, with a tapping period of 100 day year⁻¹, and with a population of 1,000 palm ha⁻¹, then an annual sap yield of 50,000-100,000 L ha⁻¹ year⁻¹ could be achieved from this palm. In alcoholic fermentation, sap with a minimum sugar content of 15 wt.% is converted to ethanol with a yield of ~0.48 gr-ethanol gr-sugars⁻¹. Consequently, the annual ethanol yield is estimated to be 4,550–9,100 L ha⁻¹ year⁻¹. Using this result for 1.23 Mha of *N. fruticans* plantations in Indonesia, Papua New Guinea, Malaysia and the Philippines [7], the annual ethanol production may reach 5,590–11,180 ML year⁻¹ [9]. Because palms do not require much fertilizer or particular care, and since they are able to live long and can be tapped for up to 50 years, their utilization would be more environmentally-friendlier compared with corn and sugarcane. Sustainable bioethanol production from palm sap could be achieved with the proper integration of sap exploitation alongside existing palm industries and plantations.

Nevertheless, exploitation of mangrove areas as nipa habitat which continuously occurred will be potentially reducing the diversity of plant species including its benefits. Mangrove as a major habitat for nipa continuously harmed, as happened in most of the northern coast of Sumatra. Mangrove ranges in the Banyuasin (including Sungasang) were decreased by 20,546.5 ha from 1992 to 2003 [10]. The data in 2006 were also discovered that 55.4% (158,989.39 ha) mangrove region in Banyuasin II area (including in Sungasang) categorized as moderate to severe harmed and only 44.6% (127,983.57 ha) categorized in great condition [11].

Therefore, it needs a habitat conservation strategy to be able to build collaborative ecological interests and socioeconomic benefits for coastal households. This research is conducted in order to conserve the existence of nipa in its habitat as well as to assess the economic value as ethanol producer in Sungasang-South Sumatera, as one of wide nipa habitat. This research calculated the potential income for households (i.e. average revenue) and labour recruitments. This research is expected to advance the description of *N. fruticans* benefits as a non-timber commodity, which at the end deforestation and land degradation that occurs in the mangrove forest can be reduced.

2. Methods

The study was conducted in Sungasang, which administratively located in Banyuasin II District, Banyuasin Regency, South Sumatra Province. The area of study is located at 2º 16’ 33” S to 2º 30’ 31” S and 104º 45’ 10” E to 104º 55’ 4” E. Topographically, the site is a swampy area with a moderate tidal influence.

2.1. Data acquisition

The number of fruit stalks was collected from Hidayat [12]. Sampling acquisition of nipa was conducted on eight-plots with three sub-plots repetition in each plot [12]. Each sub-plot samplings were measured in 10 x 10 square meters. The Plot I was adjacent to agricultural land and plantations, Plot II was adjacent to plantations. Plot III and VII were located contiguous with the settlement; Plot IV, V and VI were as undisturbed sites type; and, Plot VIII was located adjacent to agricultural land, plantations and the settlement. Data were collected from February to March 2013 [12]. If a sap yield of 0.5–2.0 L palm⁻¹ day⁻¹ is assumed, with a tapping period of 100 day year⁻¹ [8, 13], then, further processing of nipa sap would be capable to generate 8.98% [14] to15% [8] per volume of bioethanol,
then the potential bioethanol which can be produced is = 8.98% x nipa sap production \( \leq \) potential bioethanol \( \leq \) 15% x nipa sap production \( \text{L ha}^{-1}\text{day}^{-1} \). Therefore, the potential bioethanol, which can be produced in SungSang, is shown in Table 1.

2.2. Data analysis

Based on 2013 data [15], the price of bioethanol was about IDR 9,200 to 9,400 \( \text{L}^{-1} \). Therefore, potential total revenue \((TR)\) would be 0.12 x IDR 9,200 \( \leq \) TR \( \leq \) 136.65 x IDR 9,400 or IDR 1,104 to 1,284,510 \( \text{ha}^{-1}\text{day}^{-1} \). If total production cost \((TC)\) to produce bioethanol is approximately IDR 3,000 [15], then TC would be around IDR 360 to 409,950. Therefore, nett income \((NI)\) received would potentially be TR – TC or about IDR 744 to 874,650 \( \text{ha}^{-1}\text{day}^{-1} \).

In order to evaluate the expediency of labour recruitment, the previous values are compared with South Sumatera Province minimum regional wage. Based on 2013 data [15], minimum regional wage was IDR 1,974,000 month\(^{-1}\). Therefore, labour recruitment can be estimated as = \( NI \) in a year /12/ 1,974,000.

Table 1. Potential bioethanol production in the field

| Plot Number | Ave. number of fruit stalks\(^a\) (ha\(^{-1}\)) | Nipa sap\(^b\) (L ha\(^{-1}\) day\(^{-1}\)) | Bioethanol production\(^c\) (L ha\(^{-1}\) day\(^{-1}\)) |
|-------------|---------------------------------|-----------------|-----------------|
|             | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| I           | 354.22 | 177.11 | 708.44 | 15.90 | 106.27 |
| II          | 198.05 | 99.03 | 396.10 | 8.89 | 59.42 |
| III         | 392.32 | 196.16 | 784.64 | 17.62 | 117.70 |
| IV          | 269.83 | 134.92 | 539.66 | 12.12 | 80.95 |
| V           | 455.49 | 227.75 | 910.98 | 20.45 | 136.65 |
| VI          | 63.73 | 31.87 | 127.46 | 2.86 | 19.12 |
| VII         | 15.33 | 7.67 | 30.66 | 0.69 | 4.60 |
| VIII        | 2.67 | 1.34 | 5.34 | 0.12 | 0.80 |

\(^a\) Primary data generate from Hidayat [12].
\(^b\) Secondary data generate from Tamunaidu et al. [8] that 0.5 L palm\(^{-1}\) day\(^{-1}\) and based on Matsui et al. [13] that 2.0 L palm\(^{-1}\) day\(^{-1}\).
\(^c\) Secondary data generate from Trisasiwi et al. [14] that nipa sap would be capable to generate 8.98% per volume of bioethanol and based on Tamunaidu et al. [8] generate up to 15% per volume of bioethanol.

In order to evaluate the correlation between the average number of fruit stalks \((x)\) and \(NI\) \((y)\), and the average number of fruit stalks \((x)\) and the labour recruitment \((y')\), a Pearson correlation coefficient test was conducted using the following formula:

\[
r = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{\sqrt{\left( n \sum x_i^2 \sum y_i^2 \right)^{1/2}}} \]

Because both of the results were different in value and unit, the number will be transferred in natural logarithm, ln\((x)\) and ln\((y)\), and ln\((x)\) and ln\((y')\) before this test. In order to evaluate the correlation coefficient \((r)\) between the average number of fruit stalks \((x)\) and the labour recruitment \((y')\) use the above formula with \(y\) replaced by \(y'\). To statistically test, then arranged hypothetic that \(H_0: r = 0; \ H_1: r \neq 0, \ \alpha = 0.01\). The value of \(r = 0\) means that there isn’t any correlation between the number of fruit
stalks (x) and NI (y), and the number of fruit stalks (x) and the labour recruitment (y'), in reverse, the value of r ≠ 0 means that there is a correlation. The r value will not exceed from |1| when approaching to the value of -1 means that there is a negative linear relationship, and when approaching to the value of 1 means that there is a positive linear relationship. In order to assess the degree of significance, a t-test in ANOVA with α = 0.01 was also conducted. If r ≠ 0, p-value < α means that the correlation between two factors is significant, and if p-value < α means that the correlation between two factors is not significant.

The results were expected to be a general description of advantages of the nipa palm sap utilization in order to increase the welfare of the community. If the result significant shows the benefits, from the economic viewpoint, even though tapping of nipa saps could be labour-intensive, it will create a considerable number of jobs and help generate sustainable livelihood [8]. As the result, deforestation and land degradation that occurs in the mangrove forest can be reduced.

3. Results

Nipa thrives well in the mangrove environment, favouring brackish water environments such as estuaries or shallow lagoons. Nipa also colonizes the upper tidal reaches of rivers, semi-liquid mud of estuaries. At the study area, the abundant number of nipa community were found in the area that has not been disturbed by human activities (such as plantation, settlements and other massive infrastructures). Based on Table 1, the data can generate the potential economic value of bioethanol derived from nipa palm sap in a year as described in Table 2. The values were various, but generally, the abundant number of nipa communities showed high value potential economic advantages.

For example, in plot samples I to V potential nett income can be generated about IDR 5,513,288 to 87,454,080 ha\(^{-1}\) year\(^{-1}\) or about IDR 459,441 to 7,287,840 ha\(^{-1}\) month\(^{-1}\). In addition, the number of sap production days and fruit stalk length was found to be highly correlated with sap yield [16]. This value also corresponds with potential value in other sites. The estimated annual ethanol yield from nipa sap in the east coast of Southern Thailand of 4,550-9,100 L ha\(^{-1}\) year\(^{-1}\) [7] was as competitive as 5,300-6,500 L ha\(^{-1}\) year\(^{-1}\) estimated in sugarcane and 3,100-3,900 L ha\(^{-1}\) year\(^{-1}\) for corn as reported by Marris [17]. This demonstrates the wide ecological amplitude of the nipa palm [18,19]. Nipa palm populations collected from China, Thailand, Japan and Vietnam showed low genetic diversity [20]. Most of the nipa palm populations were found in the more brackish mangrove forest strips, situated further inland and away from the direct exposure to pure seawater [21].

### Table 2. Potential economic value of bioethanol from nipa sap in a year

| Plot Number \(^{a}\) | Bioethanol production \(^{b}\) (L ha\(^{-1}\) year\(^{-1}\)) | \(TR\) \(^{c}\) (IDR ha\(^{-1}\) year\(^{-1}\)) | \(TC\) \(^{d}\) (IDR ha\(^{-1}\) year\(^{-1}\)) | \(NI\) \(^{e}\) (IDR ha\(^{-1}\) year\(^{-1}\)) |
|----------------|-----------------|--------------------|--------------------|-----------------|
| Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| I | 1,590.45 | 10,626.6 | 14,632,140 | 99,890,040 | 4,771,350 | 31,879,800 | 9,860,790 | 68,010,240 |
| II | 889.24 | 5,941.5 | 8,181,008 | 55,850,100 | 2,667,720 | 17,824,500 | 5,513,288 | 38,025,600 |
| III | 1,761.52 | 11,769.6 | 16,205,984 | 110,634,240 | 5,284,560 | 35,308,800 | 10,921,424 | 75,325,440 |
| IV | 1,211.54 | 8,094.9 | 11,146,168 | 76,092,060 | 3,634,620 | 24,284,700 | 7,511,548 | 51,807,360 |
| V | 2,045.15 | 13,664.7 | 18,815,380 | 128,448,180 | 6,135,450 | 40,994,100 | 12,679,930 | 87,454,080 |
| VI | 286.15 | 1,911.9 | 2,632,580 | 17,971,860 | 858,450 | 5,735,700 | 1,774,130 | 12,236,160 |
| VII | 68.83 | 459.9 | 633,236 | 4,323,060 | 206,490 | 1,379,700 | 426,746 | 2,943,360 |
| VIII | 11.99 | 80.1 | 110,308 | 752,940 | 35,970 | 240,300 | 74,338 | 512,640 |

| a | Primary data generate from Hidayat [12]. |
| b | Secondary data generate from Tamunaidu et al. [8] that tapping period of 100 day year\(^{-1}\). |
| c, d, e | Secondary data modified from Bappeda Kabupaten Banyuasin [15] and self-data measurement. |
Tapping palm for bioethanol production can generate work and income for local farmers and encourage them to maintain the local palm population rather than replacing it with other industrial crops. In order to evaluate labour recruitment, the value can be generated from South Sumatera Province minimum regional wage compared to the value of $NI$. To compare the nett income and the number of labour recruitment with the minimum regional wage was IDR 1,974,000 month$^{-1}$ based on 2013 data [15], Table 3 is presented below.

### Table 3. Potential monthly labour recruitment based on nett income compared to minimum regional wage.

| Plot Number $^a$ | Labour recruitment $^b$ (person ha$^{-1}$) |
|------------------|------------------------------------------|
|                  | Min. | Max. |
| I                | 0.42 | 2.87 |
| II               | 0.23 | 1.61 |
| III              | 0.46 | 3.18 |
| IV               | 0.32 | 2.19 |
| V                | 0.54 | 3.69 |
| VI               | 0.07 | 0.52 |
| VII              | 0.02 | 0.12 |
| VIII             | 0.003 | 0.022 |

$^a$ Primary data generate from Hidayat [12].

$^b$ Secondary data modified from Bappeda Kabupaten Banyuasin [15] and self-data measurement.

The evaluations showed that the potential labour recruitment on the utilization of nipa palm sap into bioethanol can generate up to 3.69 person ha$^{-1}$ month$^{-1}$. This number is significant to increase the welfare of the households when compared to available or existing job field. In addition to growing nipa for its bioethanol, there are other advantages of growing nipa. The continuous productivity of nipa means no displaced labour, which is one of a major problem in sugarcane ecosystem [6]. Furthermore, replanting and rotation do not interrupt production of nipa. Other advantages are no bagasse disposal problem and nipa does not compete with other crops for agricultural land except where total reclamation is undertaken on mangrove land [6]. Tapping of nipa saps could be labour-intensive and it will create a considerable number of jobs and help to generate sustainable livelihood for the coastal communities [8, 22].

### 4. Discussions

These advantages were also observable through correlation between the average number of fruit stalks (Table 1) and $NI$ (Table 2). The test using Pearson correlation coefficient, the value of $r = 1$ (reject $H_0$), with $p$-value = 0.003 < $\alpha$ = 0.01 shows high significance. This can conclude that the number of fruit stalks was linearly a significant influence on the nett income of the households at a high level. The same results were also achieved through correlation between the average number of fruit stalks (Table 1) and labour recruitment (Table 3). Based on the test using Pearson correlation coefficient, the value of $r = 0.99$ (reject $H_0$), with $p$-value = 0.003 < $\alpha$ = 0.01 also shows high significance. This also can be described that the number of fruit stalks was linearly a significant influence on labour recruitment in a high level. These results indicate that the importance of preservation of nipa palm fruit stalks to produce benefits to the communities. Therefore, mangrove ecosystem as $N. fruticans$ habitat must be immediately conserved in order to sustain these resources. Since nipa palm sap is still underutilized for its further potential uses such as bioethanol, its survival and sustainability are threatened by other human needs.
Palms can yield sap for many years: 30 years for *B. flabellifer*, 20 years for *C. nucifera*, 50 years for *N. fruticans*, and 25 years for *P. sylvestris*. Logging and replanting, which are necessary for the harvesting sugar and starch crops, can, therefore, be reduced for tapped palms [9]. Harvesting of traditional energy crops often produces large volumes of biomass wastes such as straw, leaves and bagasse [6, 23]. Sugar extraction from sugarcane involves extra investment in equipment and energy for compression of the stem [6]. Thus, direct tapping of palms for bioethanol production may become more convenient and economical than conventional crops. Tapping palm sap for bioethanol production may compete with other palm products. For example, tapping female flowers sacrifices fruit formation. Tapping may also reduce fruit yield from the palm. Sap and other palm products should be considered to achieve sustainable bioethanol production. Palms that yield sap as the main product are suitable for ethanol production.

Free sugars in palm sap can be converted directly into ethanol without complex pre-treatment and hydrolysis that are required for starch or lignocellulosic feedstock [4]. Moreover, fermentation of lignocellulosic materials requires an external supply of nutrients to maintain microorganism activity [24]. In contrast, palm saps contain inorganics, amino acids, and vitamins, which can play their role as nutrients during fermentations [25]. Nipa sap and oil palm trunk sap were shown to produce ethanol without nutrient supplements [25]. Thus, using palm sap instead of lignocellulosics could reduce nutrient costs, although additional fermentation time may be required to achieve a high ethanol yield [8].

Generally, the level of income and education of the coastal communities which relatively low are some of the weakness factors and an internal constraint in managing sustainable mangrove ecosystems. Where large-scale removal and degradation of mangroves have already taken place [26], then the recognition of the role of mangrove in the present policy scenario is very important. Institutions (i.e. government and non-government organizations) as one component of mangrove ecosystem management play an important role in triggering and enhancing the roles as well as the community. Legislations, good governance and role of stakeholders are important to avoid conflict of interest between institutions. Proper protections are needed as considering this mangrove ecosystem as its habitat are vulnerable to human interest, for example for ponds. The habitat needs to be protected as an integral part of mangrove forests. Such studies are useful for better understanding of goods and services provided by mangroves. This may influence the awareness and perception of the local people as well as the policymakers to go along way in eliciting support for the conservation of mangrove ecosystems [26].

These indicative results of the study suggest that contribution of nipa sap is of significant economic importance, as it increases the resilience and sustainability of the local economy. This study can be an initial assessment of the usefulness of nipa palm to be further processed into a potential economic resource, which can increase income and labour recruitment to the coastal communities. Furthermore, this must be complemented with the further study of the impact of incremental changes in the mangrove ecosystems and their productivity.

5. Conclusions
The research has shown the advantages of the usefulness of nipa palm sap processed into bioethanol that from potential economic value can increase the income of the households. The highest potential annual nett income received by community up to IDR 87,454,080 or equally to IDR 12,679,930 month\(^1\). These benefits can also recruit the labour up to 3.69 person ha\(^1\) month\(^1\). The result has also described that the more nipa communities can be found then significantly the potential income of the households could potentially be increased and more labour can be recruited. Based on the research, it is important to conserve *N. fruticans* habitat to continue providing benefits to coastal households, especially utilization of nipa sap as a non-timber product.

6. References
[1] U.S. EIA [United States of Energy Information Administration] 2014 http://www.eia.gov/
countries/cab.cfm?fips=ID [16.10.2017].

[2] Kumar A, Kumar K, Kaushik N, Sharma S and Mishra S 2010 Renewable energy in India: Current status and future potentials Renew. Sustain. Energy Rev. 14 2434-42

[3] Gupta N and Kushwaha H 2011 Date palm as a source of bioethanol producing microorganisms In Date Palm Biotechnology, eds Jain SM, Al-Khayri JM and Johnson DV, Springer, Dordrecht 711-27

[4] Zabed H, Faruq G, Sahu JN, Azirun MS, Hashim R and Nasrulhaq Boyce A 2014 Bioethanol production from fermentable sugar juice Sci. World J. 2014 957102

[5] Everett B, Boyle G, Peake S and Ramage J (Eds.) 2012 Energy Systems and Sustainability: Power for a Sustainable Future, 2nd ed, University Press, Oxford

[6] Hamilton LS and Murphy DH 1988 Use and management of nipa palm (Nypa fruticans, Arecaceae): A review Econ. Bot. 42 206-13

[7] Tamunaidu P and Saka S 2013 Comparative study of nutrient supplements and natural inorganic components in ethanolic fermentation of nipa sap J. Inst. Energy 92 181-6

[8] Tamunaidu P, Matsu N, Okimori Y and Saka S 2013 Nipa (Nypa fruticans) sap as a potential feedstock for ethanol production Biom. Bioe 52 96-102

[9] Van Nguyen D, Harifara, Rabemalonontsoa and Saka S 2016 Sap from various palms as a renewable energy source for bioethanol production Chem. Ind. Chem. Eng. Q. 22 355-73

[10] Ridho RM, Sundoko A and Ulqodry TZ 2006 Analysis of changes of mangrove area in Estuary of Banyuasin River, Sungsan and Upang South Sumatra Province using Landsat-TM Satellite Imagery J. Pengelolaan Lingk. SDA 4(2) 11-18 [Indonesian]

[11] Indonesian Ministry of Forestry 2006 Inventory and Identification of Mangrove Province of South Sumatra and Bangka Belitung Islands. Book I (Main) Multima Krida Cipta, Jakarta [Indonesian]

[12] Hidayat IW 2015 Natural production potency of nipa (Nypa fruticans) sap as production commodity for bioethanol Pros. Sem. Nas. Masy. Biodiv. Indon. 1(1) 109-13

[13] Matsui N, Okimori Y, Takahashi F, Matsumura K, Bamroongrugsa N 2014 Nipa (Nypa fruticans Wurmb.) sap collection in Southern Thailand: I. Sap production and farm management Environ. Nat. Resour. Res. 4(4) 75-88

[14] Trisasiwi W, Asnani A and Setyawatty R 2011 Optimization of bacterial doses and incubation time on bio-ethanol fermentation of nipah (Nypa fruticans) for biofuel energy J. Life Sci. 5 1022-9

[15] Regional Development Planning Board and Capital Investment of Banyuasin Regency [Bappeda Kabupaten Banyuasin] 2014 Banyuasin in Number 2013 (Banyuasin: Regional Development Planning Board and Capital Investment of Banyuasin Regency) [Indonesian]

[16] Rasco Jr ET, Ragas RG and Junio RG 2012 Morphological and sap yield variation in Nipa (Nypa fruticans Wurmb.) Asia Life Sci. 21 123-32

[17] Marris E 2006 Sugar cane and ethanol: Drink the best and drive the rest Nature 444 670-2

[18] Giesen W, Wulffraat S, Zieren M and Scholten L 2006 Mangrove Guidebook for Southeast Asia, Part VIII: Palms, Cycads & Pandans (Bangkok: FAO and Wetlands International)

[19] Teo S, Ang WF, Lok AFSL, Kurukulasuriya BR and Tan HTW 2010 The status and distribution of the Nipah palm, Nypa fruticans Wurmb. (Arecaceae), In Singapore Nat. Singapore 3 45-52

[20] Jian S, Ban J, Ren H and Yan H 2010 Low genetic variation detected within the widespread mangrove species Nypa fruticans (Palmae) from Southeast Asia Aquat. Bot. 92 23-7

[21] Theerawitaya C, Samphumphaung T, Cha-um S, Yamada N and Takabe T 2014 Responses of Nipa palm (Nypa fruticans) seedlings, a mangrove species, to salt stress in pot culture Flora 209 597-603

[22] Ame RB, Ame EC and Ayson JP 2011 Management of the nypa mangrove as a mitigating measure against resource over-utilization in Pamplona, Cagayan Kuroshio Sci. 5 77-85

[23] Thatori H, Dash PK, Mohapatra S and Swain MR 2016 Bioethanol production from tuber crops using fermentation technology: A review Int. J. Sustain. Energy 35 443-68
[24] Ingram LO, Gomez PF, Lai X, Moniruzzaman M, Wood BE, Yomano LP and York SW 1998 Metabolic engineering of bacteria for ethanol production Biotechnol. Bioeng. 58 204-14
[25] Kosugi A, Tanaka R, Magara K, Murata Y, Arai T, Sulaiman O, Hashim R, Hamid ZAA, Yahya MKA, Yusof MNM, Ibrahim WA and Mori Y 2010 Ethanol and lactic acid production using sap squeezed from old oil palm trunks felled for replanting J. Biosci. Bioeng. 110 322-5
[26] Hussain SA and Badola R 2010 Valuing mangrove benefits: Contribution of mangrove forests to local livelihoods in Bhitarkanika Conservation Area, East Coast of India Wetlands Ecol. Manage. 18 321-31