Towards paludicultural agroforestry: Land use practice based on Malay local wisdom to support peatland rehabilitation in Riau Province, Indonesia

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SUMMARY

Riau Province hosts the most extensive peatland on the Indonesian island of Sumatra, covering a land area of 4.044 million hectares which is almost 45 % of the province's total area. Natural peatland has unique hydrological characteristics which mean that it often becomes degraded rapidly when utilised for purposes such as plantations, agriculture and human settlements. On the other hand, communities of indigenous Malay people have derived their livelihoods from such land for many generations. Paludicultural agroforestry has emerged as a strategic new approach for effectively managing and improving the condition of degraded peatland that simultaneously offers solutions to several connected societal and ecological challenges. Recognising parallels with traditional systems for livelihood support, our research aims to explore how land management practices rooted in the culture of Malay people in Riau might inform the modern development of paludicultural agroforestry. In this article we describe 13 different land management systems from nine Malay village communities in Riau, and explore the cultural background from which they have evolved. The study sites are distributed across three regencies, namely Kepulauan Meranti, Bengkalis and Indragiri Hilir.

KEY WORDS: agriculture, conservation, forestry, peatland management, traditional ecological knowledge

INTRODUCTION

Amongst tropical nations, Indonesia hosts one of the largest expanses (13.43 Mha) of peatland, and 44 % of this area is on Sumatra Island. Riau is the province with the most significant total area of peatland, with 3.57 million hectares peat-covered, which amounts to 27 % of the total area of Sumatran peatland (Anda *et al*. 2021). Since 2016 there have been concerted efforts to rehabilitate degraded tropical peatland in Indonesia through a comprehensive approach known as the '3Rs' strategy that encompasses the three key components of rewetting, revegetation and revitalisation of local livelihoods.

Agroforestry is a land management practice involving the intentional cultivation of a combination of trees and agricultural crops (Rotinsulu *et al.* 2022) that can be used to promote the revegetation and rehabilitation of degraded peatlands, especially if the crops are selected for significant economic value (Ulya *et al.* 2023). However, agroforestry may still require drainage, so does not halt the progressive disappearance of peat through decomposition in all of its implementations (Tata 2019a). In contrast, paludiculture is a strategic endeavour aimed at the restoration of disturbed peatlands (Prastyaningsih *et al.* 2019, Budiman *et al.* 2020) that entails cultivating crops on peatland whilst maintaining a no-drainage situation (Uda *et al.* 2020), with the primary objective of preserving peat resources and even facilitating the creation of new peatlands (Tan *et al.* 2021).

Paludiculture is now emerging as a viable land use for Indonesia's degraded peatlands, serving not only as a means of revegetation but also to effectively reduce land subsidence and greenhouse gas emissions (Lahtinen *et al.* 2022, Pratiwi & Yuwati 2022, Tanneberger *et al.* 2022) as well as to promote the rejuvenation of local communities (Yulianto *et al.* 2023). It also offers solutions to a variety of connected challenges such as poverty alleviation, climate change and fire risk mitigation, water resource management, resolution of land disputes, food security, preservation of biodiversity, and peatland restoration. Thus, it can avert both societal and ecological disadvantages of drainage-dependent land utilisation (Tata 2019b). Various paludiculture crops have been suggested as viable options for the Indonesian forestry, agroforestry and agro-food production sectors as well as to yield sources of energy, construction materials and biochemical products (Ahmad *et al.* 2022, Applegate *et al.* 2022). Thus, agroforestry-based paludiculture (paludi-cultural agroforestry) has potential as a more sustainable land use than smallholder oil palm and

pulp wood farms on peatland, that could offer a diverse range of commodities and ecosystem services whilst also alleviating the negative environmental consequences of recent peatland management practices. For regions where local people rely on peatlands for their livelihoods, it is a viable land use option that also provides protection against fires originating from drained areas and serves as a hydrological buffer surrounding the remaining peat swamp forest (Pecchioni *et al.* 2020, Applegate *et al.* 2022, Li *et al.* 2022). In other words, it offers a means to simultaneously address environmental concerns, restore the proper functioning of peatlands, and contribute to local livelihoods by producing food and other valuable commodities (Tata 2019b, Miller 2022).

Numerous research projects have reached the consensus that active engagement of the local population plays a pivotal role in achieving favourable outcomes in peatland restoration (Harrison *et al*. 2020, Yuwati *et al*. 2021, Tan *et al*. 2022). Along the eastern coast of Sumatra, the predominant ethnicity of native local people is Malay. Most Malay people in Indonesia originated from the same ethnic group as the people of Malaysia, namely the Melayu (Malays), but there are several differences in language, culture, arts and social diversity among Malay sub-groups. This is because the core Malay ethnic group dispersed to various corners of the Malay world, resulting in the assimilation of Malay sub-groups with several other ethnic groups in certain parts of the Maritime Southeast Asia region. Each traditional Malay settlement then developed its own tribal characteristics such as dialects, mottos and songs, ethnic mixing, inheritance systems, and different rituals. Thus, numerous tribes of Malay people have lived traditionally in the peat swamp forest ecosystem. In general, however, Malay communities consider the conception of forest to be very important because forests play a significant role in both real life and supernatural beliefs (Titisari *et al*. 2019). The outcome of their interaction with the forest environment is a distinct culture based on value systems and customary practices which form a socio-cultural framework for simultaneously utilising and aiming to preserve the peatland ecosystem, that has persisted across generations. One of the traditional agricultural practices developed by Malay communities in Riau is mixed farming in peaty areas. Thus, the traditional Malay local wisdom relating to the derivation of livelihoods from wet peatland can be regarded as a repository of knowledge and technology that is highly relevant to successful implementation of the modern '3Rs' strategy.

This article arises from a larger study that aims to explore various facets of indigenous Malay cultural knowledge concerning the sustainable management of natural resources in Riau Province. A specific objective is to access the indigenous Malay knowledge that serves as the fundamental framework for the derivation of livelihoods from wet peatland, as well as to obtain biophysical data from pilot plots. Thus, we aim to elucidate how the cultural principles influence community decisions to adopt different land management systems and determine the extent to which these systems can be regarded as sustainable. The study encompasses nine villages across three districts, namely: Kedabu Rapat, Sungai Tohor and Tanjung Padang Pulau in Meranti Islands Regency; Bukit Batu, Kesumbo Ampai and Titi Akar in Bengkalis Regency; and Sungai Piring, Kuala Lahang and Bekawan in Indragiri Hilir Regency (Figure 1). In addition to field measurements at the pilot plots, it incorporates a qualitative social research methodology involving informal discussions with villagers (community leaders, heads of government, village chiefs, farmers, planters, etc.) to gather descriptive data on local wisdom and practice amongst Malay communities.

In this article we report only initial information gathered during our preliminary field surveys and meetings with informants who are cultural figures in their communities and, therefore, possess a comprehensive understanding of Malay culture. The objectives are to describe and categorise the various local livelihood support systems that we observed, and to outline fundamentals of indigenous Malay culture that influence community approaches to the management and utilisation of peatlands.

MALAY PEATLAND AGRICULTURE

The livelihood support systems practised by Malay people in Riau still include the use of some resources gathered from unconverted forest, but are nowadays predominantly agricultural with incorporation of arboreal vegetation and seasonal crops in agroforestry-type configurations, often alongside livestock and aquatic farming. Farmers' choices of produce are influenced in detail by three key factors, namely: (1) sociological facets of Malay culture; (2) the ecological characteristics of the peatland; and (3) the economic valuations of different crops. Traditional knowledge and technologies are applied in operations including site selection, the choice of appropriate seeds and plants, preparation of the land for planting, cultivation, harvesting, and post-harvest processing.

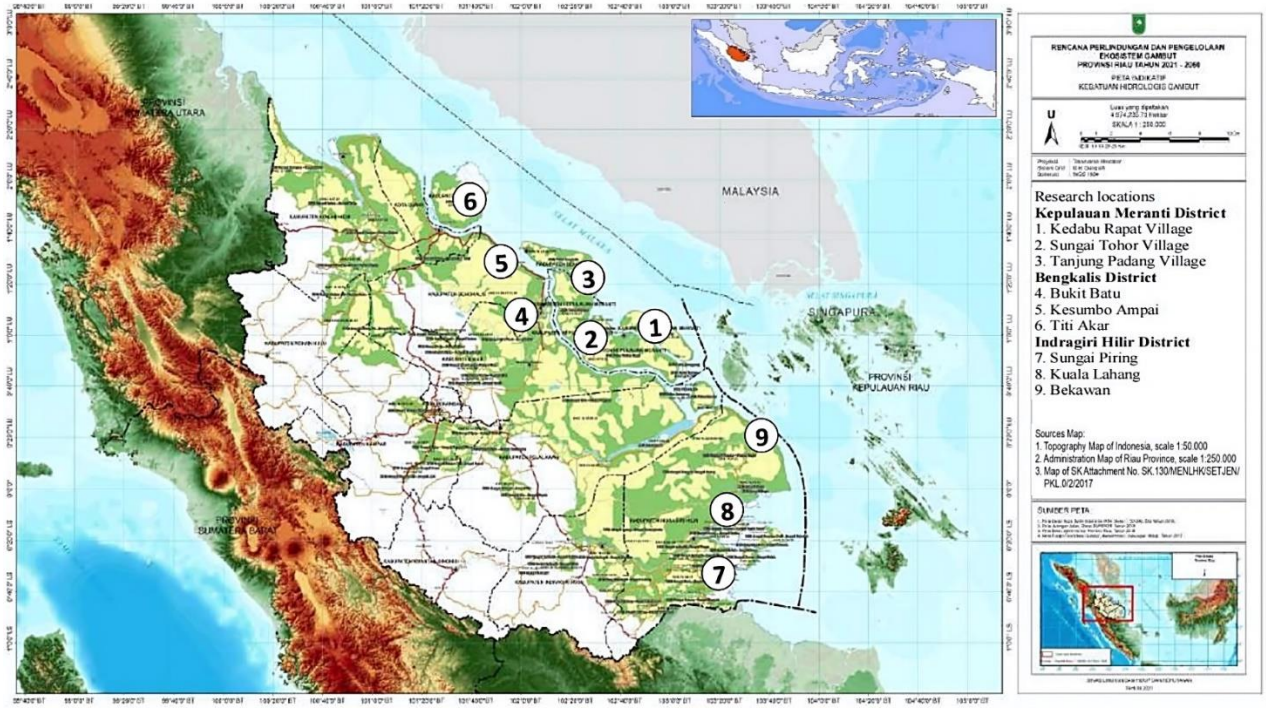

Figure 1. Locations of the research sites (see legend).

Emphasis is placed on the utilisation of indigenous plant species, which can be categorised into four main groups, namely:

(1) woody plants/trees such as bintangur (*Calophyllum inophyllum* L.), punak (*Tetramerista glabra* Mig.), pulai rawa (*Alstonia scholaris* (L.) R. Br, jelutung rawa (*Dyera polyphylla* (Miq.) V.Steenis.) and aloes (*Aquilaria* spp., *Gonystylus* spp., *Gyrinops* spp.);

(2) food crops such as sago (*Metroxylon sagu* Rottb.), rice (*Oryza sativa* L. var. Inpari 23, 29, Mundam, Sunting), corn (*Zea mays* L. var. Simoleh and Mitro) and cassava (*Manihot esculenta* Crantz var. Gebang, Adira 2 and 4);

(3) plantation crops such as coconut (*Cocos nucifera* L.), rubber (*Hevea brasiliensis* Muell. Arg.), oil palm (*Elaeis guineensis* Jacq.), Liberica coffee (*Coffea liberica* Hiern.), durian (*Durio zibethinus* Murr.), pineapple (*Ananas comosus* (L.) Merr.), jengkol (*Archidendron pauciflorum* (Benth.) I.C.Nielsen), betel nut from the areca palm (*Areca catechu* L. var. Batara), the bananas pisang kepok (*Musa acuminata balbisiana* Colla) and pisang tanduk (*Musa paradisiaca* fa. *typica*), and dragon fruit (*Hylocereus* sp.); and

(4) horticultural plants including chilli pepper (*Capsicum annum* L.), eggplant (*Solanum melongena* L.) and cucumber (*Cucumis sativus* L.) as well as various spices and medicinal plants.

Of particular note are sago, coconut, areca palm and rubber, which can retain and store water during the dry season and are commonly utilised by the Malay community in Riau as sources of livelihood in peatland areas (Safitri 2020, Dewi *et al.* 2021, Fatkhullah *et al.* 2021, Armanto 2022).

The detailed implementation of peatland management by Malay communities across our study area is contingent upon the individual characteristics of the respective peatlands. In total there are thirteen distinct approaches which are rooted in the indigenous knowledge and practices of local communities. These are described in turn in the sub-sections that follow.

1) ***Kepungan sialang***

Kepungan sialang is the term used by the *Orang Rimba* ('people of the forest') to refer to a specific type of forest tree that is utilised for nesting by honey bees. During their flowering season, sialang trees are particularly favoured by the forest bee *Apis dorsata*. These trees are characterised by features including a tall trunk, a relatively open branching pattern and a crown that is not overly dense (Figure 2). They are taxonomically diverse, including species such as kedondong (*Spondias dulcis* L.), kempas (*Koompassia excelsa* (Becc.) Taub.), keruing (*Dipterocarpus* spp.), pulai (*Alstonia angustiloba* Miq), rengas (*Gluta renghas* L.) and cempedak air (*Artocarpus maingayi* King).

The *kepungan sialang* jungle holds a prominent place in the cultural heritage of the indigenous community of Pelalawan Regency as a whole, and is also prevalent in the regencies of Kampar and Kuantan Singingi. This jungle is carefully maintained on account of its significant role not only as an economic and livelihood resource but also as a crucial asset symbolising the ancestral blessings, prestige, and cultural greatness of its traditional owners.

2) ***Ghimbo***

In the province of Riau, the *ghimbo* land management system is found predominantly in the Indragiri Hulu and Bengkalis regencies. It is distinctively characteristic of two isolated indigenous communities, namely the Talang Mamak tribe in the conservation area of Bukit Tigapuluh National Park in Indragiri Hulu Regency and the Akit tribe in Bengkalis Regency. Historically, the Sakai tribe in Siak Regency and the Bonai tribe in Rokan Hulu Regency also practised *ghimbo*. However, over time, their traditional forest lands have been transformed into mining concessions, oil palm plantations and industrial timber plantations, leading to the gradual disappearance of this practice.

The *ghimbo* land of the Talang Mamak tribe is situated within the communal forest. All male members of the community collectively engage in limited forest clearing, extracting specifically designated/permitted timber, harvesting non-timber forest products such as honey, rattan (*Calamus manan*), fruits and animals hunted once a year. All harvested forest products are sold and the proceeds are utilised for the community's needs. Permissible timber species for extraction include meranti (*Shorea* spp.), durian, rattan, jengkol, petai (*Parkia speciosa* Hassk.), jernang (*Daemonorops draco* Willd.), jelutong rawa, nyatoh (*Palaguium* spp.), pulai (*Alstonia scholaris* L. R. Br.), kempas (*Koompassia excelsa* (Becc.) Taub.) and meranti (*Shorea* spp.).

3) ***Kobun***

The *kobun* system (Figure 3) is based on trees such as surian (*Toona sinensis* Roem), bayur (*Pterospermum javanicum* Jungh.), gelam (*Melaleuca leucadendron* Linn.), mahogany (*Swietenia mahagoni* (L.) Jacq), sengon (*Paraserioanthes falcataria* L. Nielsen) and sungkai (*Peronema canescens* Jack) which will be processed into wood for carpentry, buildings and furniture with high selling value. Various types of fruit are also cultivated: durian, sapodilla (*Manikara zapota* L.), rambutan (*Nephelium lappaceum* L.), mangosteen (*Garcinia mangostana* Linn), sweet orange (*Citrus sinensis* L.), pisang kepok (*Musa acuminata balbisiana* Colla), papaya (*Carica papaya* L.), jengkol and petai, thus forming a pattern combining wood-producing trees with fruit trees. The main plant grown on garden land is rubber.

Figure 2. *Kepungan sialang* forest in Kepulauan Meranti District.

4) ***Campuran***

The *campuran* (mixed-type) system (Figure 4) is predominant in Riau Province. The primary plant species is rubber in conjunction with various arboreal species such as gerunggang (*Cratoxylon arborescens* (Vahl.) Blume), ramin (*Gonystylus bancanus* Kurz.), jelutung rawa, punak (*Tetrameristra glabra* Miq.), bungur (*Lagerstroemia speciosa* (L.) Pers.), swamp pigeon (*Shorea pauciflora* King), balengaran (*Shorea balangeran* Burck), bintangur (*Calophyllum inophyllum* L.), kempas (*Koompassia malaccensis* Maing. ex Benth.), nyatoh and agarwood (*Aquilaria* spp.). The selection of these trees is driven mostly by their high market value. Typically, they are harvested after they reach 15 years of age. The fruit plants commonly cultivated include durian, sapodilla, rambutan, mangosteen, sweet orange, banana, papaya, jengkol and petai.

5) ***Jalur***

Jalur is known as strip-type agroforestry practice and involves the cultivation of forest plants in a strip with non-forest crops, particularly fruit and occasionally food crops, adjacent. This results in a pattern of alternating strips of forest and non-forest vegetation (Figure 5). The forest vegetation comprises gerunggang, balengaran and bintangur. These trees serve not only as marketable commodities but also as valuable resources for constructing dwellings, manufacturing home furniture, and fulfilling other essential requirements. The range of fruit plants includes pineapple (*Ananas comosus* (L.) Merr.), banana and papaya while the food crops are corn and cassava.

6) ***Sabuk***

Sabuk is a cultivated belt or block that combines forest and non-forest plants. Annual plants such as coconut or rubber are planted in the central part of the block, along with fruit plants such as pineapple, durian, sapodilla, rambutan and mangosteen. Additionally, jelutung rawa, punak, bungur, agarwood, balengaran, Liberica coffee, areca palm (*Dypsis lutescens*) and sugar palm (*Arenga pinata* Merr.) are planted outside the forest edge (Figure 6).

7) ***Parak***

Agroforestry practice of the *parak* type is frequently observed within Riau Province, specifically in Kampar Regency and Kuantan Singingi Regency. Under this system, annual crops are grown in combination with trees that are diligently managed and periodically harvested. The *parak* agroforest typically includes six types of trees, namely durian, Liberica coffee, robusta coffee (*Coffea robusta* L. Linden.), surian, bayur, jengkol and petai. Additionally, it incorporates corn and cassava, as well as vegetables such as chilli pepper (*Capsicum annum* L.), cucumber (*Cucumis sativus* L.) and eggplant (*Solanum melongena* L.), medicinal spice

Figure 3. *Kobun* agroforestry system in Kepulauan Meranti District.

Figure 4. *Campuran* agroforestry system in Kepulauan Meranti District.

Figure 5. *Jalur* in Kepulauan Meranti District.

Figure 6. *Sabuk* in Indragiri Hilir District.

plants, and fruit plants including banana, papaya, sapodilla, rambutan, mangosteen, sweet orange, cocoa (*Theobroma cacao* L.) and avocado (*Persea americana* Mill.). Figure 7 depicts the agroforestry system of *parak.*

8) ***Parit / parit kongsi***

This is a method of land management along riverbanks that has been practised by farmers on peatlands in Indragiri Hilir Regency since ancient times. A series of ditches with flanking embankments is constructed perpendicular to the bank of the main river. The embankments are commonly used as roads and property boundaries. Land ownership boundaries are typically planted with coconut or rubber. The ditches may be regarded as secondary conduits within a framework where rivers are regarded as major conduits. Cultivation of the peatland between ditches commences gradually in harmony with changes in land conditions, tidal influences (water depth) and peat thickness. The food crops are rice, corn and cassava, which are rotated seasonally. Additionally, fruit plants such as pineapple, durian, sapodilla, rambutan and mangosteen are grown, with farmers' crop choices at any time being influenced by variations in their commercial value. This system is illustrated in Figures 8 and 9.

9) ***Handil***

The *handil* system (Figure 10) involves the construction of a channel (*handil*) of width 1–2 m and depth 0.5–1.0 m that extends from the river channel for 1–2 km. This allows the ingress of water through the handil during high tide, while facilitating the egress of water to the river during low tide. Additionally, this model facilitates domestic laundry which is simply deposited in a *handil*. In situations where a substantial volume of water is needed over an extended period, farmers can impede the flow of water in a channel by constructing a barrier using materials such as wood or soil. The barrier serves to prevent water from being lost as runoff, instead retaining it within the channel and allowing its collection or storage. The present-day *handil* agricultural system has developed from its original rudimentary form and is commonly employed for the cultivation of rice in conjunction with fruit crops such as pineapple, banana, papaya and watermelon (*Citrullus lanatus* (Thunb.) Matsum. &. Nakai), occasionally accompanied by vegetables and herbs.

10) ***Anjir***

The system known as *anjir* integrates agricultural land on both banks of two major rivers. As in the *handil* system, land situated on both the left and right riverbanks has been transformed into agricultural land. The construction of the *anjir* is expected to have a positive effect on water management in the surrounding area, particularly in relation to its suitability for rice cultivation. Subsequently, a considerable number of individuals have autonomously established rice fields in the vicinity of the *anjir* canal, leading to its gradual transformation into a residential zone. This phenomenon is particularly prominent among farmers who engage in agricultural activities inside the rice fields around the *anjir* wetlands. In addition to rice, fruit plants such as pineapple, banana and watermelon are cultivated, as in the practice of *handil*. The embankments of rivers are commonly planted with various vegetable crops including chilli pepper, cucumber, eggplant, tomato (*Solanum lycopersicum* Mill.), shallot (*Allium cepa*

Figure 7. *Parak* agroforestry system in Kepulauan Meranti District.

Figure 8. Hydrological system model of peatlands which are used for various types of paludicultural agroforestry in Indragiri Hilir District.

Figure 9. *Parit Kongsi* in Indragiri Hilir District.

L.), spring onion (*Allium fistulosum* L.), kale (*Ipomoea* spp.), spinach (*Amaranthus* spp.) and medicinal spice plants.

11) ***Garpu***

The variant known as *garpu* is characterised by a water management system that incorporates channels constructed along the river's edge, extending into the interior. This system comprises a navigation channel and a primary channel, followed by a secondary channel that bifurcates into two channels, forming a network resembling a fork shape. In contrast to the agricultural practices observed in *handil* and *anjir*, where the primary cultivated areas are rice fields, the fork system described in this context focuses on the cultivation of other food crops such as corn and cassava (*Manihot esculenta* Crantz.). Additionally, vegetable crops including chilli pepper, cucumber and eggplant, as well as medicinal spice plants and fruit plants such as pineapple, banana, papaya, and watermelon, are commonly cultivated. It is worth noting that large woody trees, except for coconut (*Cocos nucifera* L.), are not planted in this system.

12) ***Sisir***

Sisir is characterised by a water management system that incorporates main channels running parallel to the river, accompanied by lengthy secondary channels. This channel system is divided into distinct water supply and drainage channels. Additionally, the secondary channels are supplemented with parallel tertiary channels, forming a network with a comb-like structure. There are similarities between this comb (*sisir*) and the fork (*garpu*) system, the main difference being the water system. In the comb system, similar crops such as corn, cassava and various vegetables including chilli pepper, cucumber, and eggplant, as well as medicinal spice plants and fruit plants like pineapple, banana, papaya and watermelon are cultivated. However, it is uncommon to find large woody trees except for coconut or rubber, as well as areca palm and sugar palm. In Bengkalis Regency, oil palm (*Elaeis guineensis* Jacq.) is also combined with these crops. Figure 11 shows an example of *sisir*.

13) ***Silvopastura***

The silvopastoral agroforestry system is a composite system incorporating various combinations of oil palm or rubber with cattle or goats, which has been widely implemented in almost all districts of Riau Province. It is also prevalent in many of the systems already described including *handil*, *kebun*, *parak*, *ghimbo*, *campuran* and *parit kongsi*. In the communal ditch systems of *parit kongsi*, *handil*, *garpu*, *sisir* and *jalur*, agrofishery and silvofishery are also practised in combination with husbandry of laying ducks. Although there are numerous reasons for the adoption of *silvopastura*, the primary aim is to increase the farmer's income by selling livestock. There is specificity in the implementation of *silvopastura* based on the ethnic communities. In Indragiri Hilir Regency the systems established in swampy areas such as *handil*, *jalur*, *sisir*, *garpu*, *anjir* and *sabuk* predominantly incorporate agrofishery, silvofishery and laying ducks. This is attributed to the dietary culture, which prioritises fish over meat. In the regencies of Kampar, Kuantan Singingi, Rokan Hulu, Rokan Hilir, Siak and Pelalawan, on the other hand, agropasture and silvopasture involving cattle and goats are favoured, owing to local dietary cultures that prioritise meat over fish.

Figure 10. *Handil* in Kepulauan Meranti District

Figure11. *Sisir* agroforestry system in Kepulauan Meranti District.

INFLUENCE OF MALAY CULTURE

Customs, traditions, and religion constitute fundamental value systems for Malay people. The Malay community in Riau Province has a strong tradition of maintaining environmental harmony, as evidenced by their proverbs, poetry, teachings, norms, behaviours, and attitudes towards environmental preservation. Nature is central to people's lives, not only because they can use it, but also because they have an obligation to protect it. Therefore, the community strives to coexist harmoniously with the natural environment. The embodiment of these principles is referred to as local wisdom, which forms the basis of specific customs that are adopted, understood and applied by the community in relating to and interacting with their environment. This knowledge has been acquired, cultivated and passed down through generations. Forms of local wisdom include wise sayings, recommended ethics or behaviours, and values and norms. Interestingly, the obligation to preserve the environment is also influenced by Islamic values asserting that humans are stewards or leaders responsible for the Earth that have been assimilated into Malay culture in Riau (Marfai 2013, Zebua *et al.* 2017, Zamhasari & Gafar 2021, Permatasari *et al*. 2024).

Expressive traditions such as ballads, proverbs, expressions, poems, instructional tales and epics play a significant role in shaping communal laws that guide the behaviour of Malay people including indigenous communities like the Talang Mamak, Sakai, Bonai, Petalangan and Orang Akit in Riau. The obligation to respect nature is reflected in proverbs (*petatah petitih*) known to the older generation, such as "*jika alam musnah maka adat istiadat pun musnah*" (if nature perishes, customs will also perish), "*kalau tidak ada laut, hampalah perut, bila tidak ada hutan, binasalah badan*" (if there is no sea, the stomach will be empty, if there is no forest, the body will perish) and "*kalau binasa hutan yang lebat, rusak lembaga hilanglah adat*" (if the dense forest perishes, institutions are destroyed, traditions are lost) (Thamrin 2014, 2015; Marlina 2020). Further examples are listed in Box 1.

The notion that forested land is the primary basis of Malay culture is emphasised. The foundation of this notion is rooted in the indigenous knowledge and practices of the Malay people, for whom the forest serves to fulfil both physical and spiritual needs (Effendy 2004, Noviana *et al.* 2023, Wahyuni *et al.* 2023). The forest is an inseparable and integral part of their culture, and the focal point for sustaining their way of life. Indeed, without the forested land, Malay culture would never have come into existence

Box 1. Some examples of traditional Malay 'rules for life' and related proverbial expressions. Sources: Thamrin (2014), Thamrin (2015), Marlina (2020).

Relating to the Malay perspective on the relationship between their own existence and their natural surroundings:

kalau tak ada laut - hampalah perut	=	if the ocean's gone - starvation is inevitable
bila tak ada hutan - binasalah badan	=	if the forest's gone - humans start to crumble
kalau binasa hutan yang lebat - rusak lembaga hilanglah adat	=	if there is no longer any dense forest - organisation and tradition turn to dust

The Malay mandate places considerable emphasis on the preservation and balance of the natural environment. It encompasses several abstentions and prohibitions that serve as guidance for individuals to refrain from causing harm to nature, exemplified by expressions such as:

adat hidup memegang adat	=	living customs hold traditions
tahu menjaga laut dan selat	=	know how to protect the seas and straits
tahu menjaga rimba yang lebat	=	know how to guard the dense jungle
tahu menjaga tanah wilayat	=	know how to protect the land
tahu menjaga semut dan ulat	=	know how to preserve ant and worm
tahu menjaga togok dan belat	=	know how to look after sticks and splints
tahu menebas memegang adat	=	know how to cut down while treasuring the tradition
tahu menebang memegang amanat	=	know how to cut down while holding to the mandate
tahu berladang menurut undang	=	know how to farm according to the law
tahu berkebun mengikut kanun	=	know how to garden according to the regulations
beramu tidak merusak kayu	=	foregathering without destroying the wood
berotan tidak merusak hutan	=	collecting rattan without destroying the forest
bergetah tidak merusak rimba	=	sapping but not destroying the jungle
berimba tidak merusak hutan	=	planting in jungle without destroying the forest
berkebun tidak merusak dusun	=	gardening without destroying the village
berkampung tidak merusak gunung	=	building the village without destroying the mountain
berladang tidak merusak padang	=	farming without destroying the fields

and flourished. In essence, the Malay community possesses an understanding of the imperative need to ensure the long-term viability and sustainability of the forest ecosystem by maintaining its ecological equilibrium.

Customary law forms the backbone of Malay life and is intimately related to the natural ecosystem of rivers and forests. The tradition that places wisdom in the forested land leads the customary law to strive consistently to maintain environmental balance (Hamidy 2002, Effendy 2004, Noviana *et al.* 2023, Wahyuni *et al.* 2023). Accordingly, the Malay are judicious in managing and utilising forest resources to sustain their livelihoods. To this end, the customary leaders have traditionally enforced stringent land zoning measures (Afandi *et al.* 2023, Noviana *et al.* 2023, Wahyuni *et al.* 2023) through the law, which incorporates concepts relating to ancestral land (*tanah ulayat*), profit sharing (*pancung alas*), forbidden (i.e. protected) forests (*hutan larangan*), reserved forests (*hutan simpanan*), *kepungan sialang* forests and land where cultivation is permitted.

The spatially based rules for land use by the indigenous community designate at least four zones. The reserved (*rimba simpanan*) and forbidden (*rimba larangan*) zones are wilderness that is intentionally left undisturbed. Its conversion into productive land such as fields or gardens is prohibited, but products that are obtained from it include wood for building houses and transportation tools such as boats, canoes, and trails. Forest products including fruits, rattan and

various game animals, birds and fish can be harvested with the knowledge of the customary leaders, but within limits that do not harm the sustainability of the forest. A saying that guides the handling of forbidden forest is: "*kayu ditebang diganti kayu, rimba ditebang diganti rimba* (felled wood is replaced by wood, felled forest is replaced by forest)" (Hamidy 2002, Effendy 2004, Noviana *et al.* 2023, Wahyuni *et al.* 2023). The other zones, which may be more heavily utilised, are backyard (*tanah pekarangan*), garden (*tanah kebun*) and agricultural (*tanah peladangan*) land, along with the surrounding forest of *sialang* trees (*rimba kepungan sialang*).

The development of community knowledge occurs at local level, where it undergoes adaptation to suit the specific conditions and needs of the community. This process involves a constant cycle of creativity and innovation, incorporating both internal and external contributions, with the aim of effectively responding to evolving local circumstances (Najiyati *et al.* 2005, Schaafsma *et al.* 2017, Tanneberger *et al.* 2020, Tan *et al.* 2021, 2022). Local knowledge is acquired and transmitted through oral traditions, primarily through verbal communication and informal education. Thus, local wisdom can be conceptualised as the cumulative knowledge and expertise passed down through generations, which adapts and evolves in response to changing circumstances and advancements over time. The ability of farmers to effectively navigate and adapt to changes is an integral component of the collective knowledge and practices within the local community. The accumulation of knowledge over many generations, through the process of repeated observations, has culminated in the development of indigenous wisdom pertaining to the utilisation of water for agricultural purposes, particularly in peat swamp areas (Hamidy 2002, Noor *et al.* 2014, Tata 2019a, Helmi *et al.* 2021, Ward *et al.* 2021). This is most clearly manifest today in the range of water management systems (*parit kongsi*, *handil*, *anjir*, *garpu*, *sisir*) that have been developed for different riverside situations.

RELEVANCE TO CURRENT PRIORITIES

In contrast to monoculture planting, the practice of agroforestry involving the cultivation of a variety of plant species within a single area can reduce the risk of crop failure, and thus better support the security of farmers' livelihoods. Nevertheless, it is imperative to combine it with rewetting operations to restore high soil moisture in arid peatlands. This aligns with initiatives to facilitate the rehabilitation of degraded peatlands, since the implementation of paludicultural agroforestry should effectively mitigate the occurrence of fires, preserve biodiversity, transform degraded land into an economic asset, and potentially offer viable resolutions to land disputes (Noor *et al.* 2014, Tata 2019a, Helmi *et al.* 2021).

The incorporation of both annual plants and trees is often regarded as a means of generating short-term revenue whilst simultaneously making a long-term investment for income generation from the eventual sale of timber. However, because trees play a crucial role in the process of capturing rainwater and subsequently storing it in the soil, the cultivation of native forest trees also serves as a mechanism for water management and regulation in peatlands. This function reduces the occurrence of water runoff on peat surfaces, which has the potential to induce erosion (Napitupulu & Mudiantoro 2015, Yuliantoro *et al.* 2016, Triadi 2020, Umami & Sari 2021, Pradana *et al.* 2022)

Thus, to achieve success in the cultivation of plants utilising the principles of agroforestry on peatlands, it is imperative to adopt a prudent approach to farming similar to that traditionally adopted by the Malay, which considers the constraining factors - particularly those relating to limited irreversible drying and minimal subsidence of peat (Najiyati *et al*. 2005). We suggest that the practices developed out of the evolving local wisdom of indigenous Malay on Sumatra can constructively inform the modern development of paludicultural agroforestry on degraded peatland. However, a verdict on whether or not any truly sustainable (and carbon neutral) solutions could be developed will require further research and field data. Research is still needed to discover which agroforestry pattern or system is the most sustainable, in terms of both the associated carbon stock and the resilience of farmers in facing the challenges of climate change.

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AUTHOR CONTRIBUTIONS

PWT and E conceived and designed the study; E collected the data; E, IC and TP analysed the data; E and PWT contributed reagents/materials/analysis tools; PWT, E, IC, TP, and N wrote the manuscript.

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