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BIODIVERSITY CONSERVATION VALUE OF TRADITIONALLY MANAGED AGROFORESTS OF SOUTH MEGHALAYA

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ABSTRACT The tribal people who live in the area have converted significant portions of lowland tropical forests in south Meghalaya into agroforestry systems. A considerable amount of the original forest biodiversity is preserved in these agroforests with diversified and structurally complex shade canopies. Standard vegetation analysis and biodiversity assessment methodologies were used to investigate the influence of land use change on plant diversity. The study suggests that agroforests developed by the indigenous War Khasi people in south Meghalaya through experience learning over several generations have emerged as a relatively resilient agroforestry system with minimal influence on plant diversity.

KEYWORDS : Betel Leaf Agroforest; South Meghalaya; Plant Diversity; Cash Crop

INTRODUCTION

Human actions have had an impact on species diversity, which has piqued ecologists' interest from both a theoretical and practical standpoint (Stapanian et al. 1997). McNaughton (1977), Frank & McNaughton (1991), and Tilman & Downing (1994) conducted experiments to support the concept that ecosystems with high species diversity are more stable and resilient to human perturbations than ecosystems with low species diversity. Diverse systems, it is suggested, are likely to contain some species that can survive during perturbation and hence compensate for those members of the community that are diminished or destroyed as a result of the disturbance (Ehrlich & Wilson 1994). Contrary to popular belief, Connell (1978) hypothesized that species diversity in rain forests will be greatest when disturbances are moderate in severity and frequency, drawing an analogy between coral reefs and tropical forests. Collins et al. (1995) hypothesized that richness should be maximum at intermediate frequencies of disturbances, where conditions favor both competitive and disturbance-tolerant species. As a result, disturbance intensity and frequency are key predictors of plant variety in a community.

The north-east region of India is regarded one of the continent's richest biodiversity hotspots. It is the center of origin of angiosperms, according to Takhtajan (1988). Meghalaya is home to 3,128 angiosperm species, including 1,237 unique species and 53 threatened plant species (Khan et al. 1997). (Nayar and Shastry 1988). A number of researchers have examined the flora of Meghalaya, including Hooker (1872-1897), Kanjilal et al. (1934-1940), Balakrishnan (1981-1983), and Haridasan and Rao (1985-1987). Sukumar et al. (1992), Parathasarathy and Karthikeyan (1997), and Joshi et al. (2001) conducted phytosociological studies in Indian forests (1997). The plant diversity of Meghalaya's sacred forests has been examined by Rao et al. (1990), Upadhaya (2002), and Jamir and Pandey (2003). However, our knowledge of the biodiversity of agroforests created and managed by local communities for long-term usage is lacking. The purpose of this research was to inventory plant diversity in traditionally managed agroforests in south Meghalaya and classify species according to their relevance based on local people's usage.

Study area

The survey was carried out in a tropical evergreen region in south Meghalaya's betel nut and betel leaf agroforests, namely Mawriang village's betel nut agroforest and Nongkwai village's betel leaf agroforest, an area very close to Bangladesh's international border (Fig. 1).The research locations are located between the latitudes of 25o6'25" and 25o18'29" N and the longitudes of 91o57'38" and 92o 1'26" E. This region contains the Cherrapunjee-Mawsynram Plateau, which is one of the wettest places on the planet (Tynsong et al. 2006). The elevation ranges from 10 meters (Shella) to 1200 meters (Pynursla). The average annual maximum temperature is around 23°C, with a minimum temperature of 13°C. The average annual rainfall is 11564.75 millimeters. Red loamy and alluvial soil are important soil types. The soil in the area is fertile and humus-rich in general. The area has a south-facing slope with an angle ranging from 100 to 400 degrees. There are numerous rivers and rivulets in the area that drain into Bangladesh's plains. There is a low population density. The people's main occupations are horticulture, forestry, and fisheries. Agriculture is restricted to a few small valleys, where tuber crops predominate. The region's main products are betel nut, orange, betel leaf, jack fruit, bay leaf, honey, and broom grass. The War Khasi, a tribal community with a long history of forest conservation, live in the area (Tiwari 2005). Fish, frogs, crabs, mollusks, bushmeats, tubers, and wild vegetables are among the delicacies collected from forests and water bodies. Rice, fish, and meat are the basic foods of the locals. Non-timber forest products (NTFPs) and medicinal and aromatic plants (MAPs) such as *Cinnamomum tamala, Piper peepuloides, Phrynium capitatum*, bamboo, honey, mushrooms, nuts, tubers, edible worms, insects, and green vegetables are collected, processed, and sold in the forests. Around 30,000 farmers are currently cultivating betel nut on around 70,000 hectares of land in south Meghalaya, whereas around 20,000 farmers are cultivating betel leaf on approximately 15,000 hare of land. Farmers in south Meghalaya have devised a method in which these 4–7 ha agroforests are closely related with local and exotic plant species.

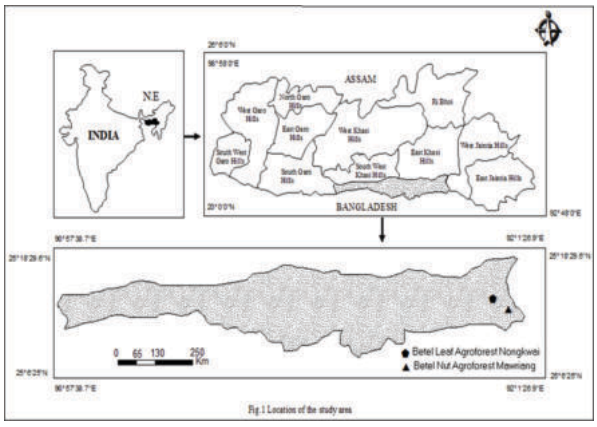

Fig.1 Location of the study area

South Meghalaya's natural vegetation varies from tropical to subtropical evergreen forests (Balakrishnan 1983). The forest's plant species are separated into different vegetation strata. *Cinnamomum tamala, Daphniphyllum himalayanse, Myrica esculenta, Sarcosperma griffithi, Syzygium tetragonum*, wild banana, and other important evergreen trees may be found in South Meghalaya. *Betula alnoides, Cedrela toona, Engelhartia spicata, Ficus roxburghii*, and other are among the deciduous elements. *Ardisia griffithii, Boehmeria malabarica, Goniothalamus sesquipidalis, Mahonia pycnophylla, Wallichia densiflora*, and other shrubs make up the shrub layer. *Borreria pilosa, Commelina benghalensis*, *Impatiens* sp., *Ophiorrhiza hispida, Sonerila khasiana*, and a vast number of ferns dominate the ground vegetation (herb). A lot of lianas and other climbers can be observed twining on the trees. The tree trunk and branches are covered in mosses, epiphytic ferns, and orchids of various varieties. Invasive weedy species such as *Artemisia* sp., *Eupatorium* sp., *Mikania micrantha*, and others are also abundant.

METHODS

Plant survey

In South Meghalaya's betel nut and betel leaf agroforests, a comprehensive survey was conducted for plant diversity studies. For a period of two years, data was collected once in each season of the year. 100 m^2 plots (10 m_2) for trees, 25 m^2 plots (5 x 5 m) for shrubs, and 1 x1 m for plants were used to determine vegetation characteristics. Each

study site had a total sample area of 0.4 hectare for trees, 0.05 ha for shrubs and climbers, and 0.01 ha for herbs. Individual betel nut and non-betel nut trees with a diameter of 5 cm or less were counted, measured, and numbered, and their density and frequency per plot were assessed. Questionnaires, focused group discussions, key informant interviews, and Participatory Rural Appraisal (PRA) procedures were used to gather information on the usage and importance of plant species, as described by Mukherjee (1993), Tiwari (2001), and Raintree (2001).

DATAANALYSIS

Plant specimens collected were identified with the help of Flora of Assam (Kanjilal *et al.* 1934-1940), Flora of Jowai (Balakhrishnan 1981-1983) and Forest Flora of Meghalaya (Haridasan and Rao 1985-1987). The identifications were confirmed by consulting the herbaria at Botanical Survey of India, North-Eastern Circle, Shillong. The nomenclatures of the species are as per the regional flora. Diversity was calculated using the Shannon and Wiener index of diversity (H^{-}) (Shannon and Wiener 1963), Simpson index of dominance (D) (Simpson 1949) and Pielou's evenness index (E) (Pielou 1975). The Shannon index tends to be slanted slightly towards less abundant or rare species, while the Simpson index favours the more abundant or dominant species (Zapfack *et al*. 2002). The two indices together give a good description of the alpha diversity (within site) of the agroforest. The Pielou evenness index provides information on the distribution of individuals among the species; it is high if all species are about similarly abundant and low if some species dominate in number.

The frequency, density and abundance of the species were determined following the methods of Misra (1968) and Muller-Dombois and Ellengberg (1974). The basal cover (m^2ha^{-1}) was calculated by using the formula: basal cover (BC) = density x average tree basal area (Khan *et al*. 1997). The importance value index was calculated by using the formula for tree: IVI = relative frequency + relative density + relative basal area and for shrub and herbs: IVI = relative frequency + relative density (Upadhaya *et al*. 2006). The data on uses of each plant species present in the agroforests are based on local use.

RESULTS:

Betel nut Agroforest: Betel nut agroforests are a type of polyculture agroforest in which the betel nut (*Areca catechu* L) is grown alongside a variety of native wild plants, some of which are economically valuable non-timber forest product species. In this sort of agroforestry system, the majority of the trees are cut in the first year, leaving a 5 × 5 m space for betel nut growth. People begin filling in the gaps with vital plant species in the second year, in addition to the main income crop (*Areca catechu*). The content and structure of betel nut agroforests are determined by the retention of forest trees and the introduction of local and exotic plants (Fig. 2). As a result, a multi-strata and multi-species agroforest emerges, with species composition reflecting local people needs.

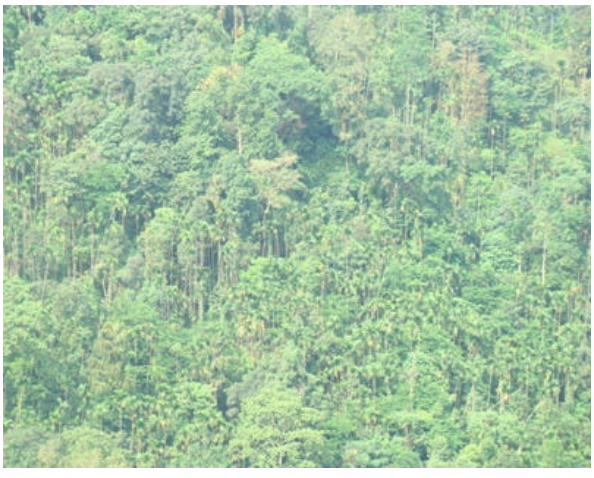

Fig. 2. Betel nut agroforest of Mawriang village

Betel leaf Agroforest: In Meghalaya, farmers plant the betel leaf (*Piper betle* L.**)** without cutting of naturally growing trees and burning of the field. Betel leaf grows in an intimate mixture along with trees, shrubs and herbs on the same piece of land. During the first year after planting the betel leaf, the farmers prune the canopy of all trees except few important timber, fruit trees and non-coppicing tree species. Cutting of tree branches is done so that the newly planted betel leaf grown at the base of the trees receives enough sunlight and nutrients from the decaying leaves and branches of the lopped trees. After three to four months, most trees start sprouting again and after one year the whole plantation looks like a natural forest again (Fig. 3). Important timber trees include *Michelia cathcartii, Toona ciliata, Cedrela toona* and *Schima wallichii,* fruit trees include *Artocarpus heterophyllus, Gynocardia odorata* and *Baccuarea sapida* and non-coppicing trees include *Macaranga peltata, Macaranga hypoleuca, Lithocarpus elegans* and *Ligustrum robustum.* The process involved in cultivation of betel leaf and management of betel leaf agroforests in Meghalaya is similar to that reported for the Khasia tribes of Bangladesh as described by Saha and Azam (2004) and Haider et al. (2013).

Fig. 3. Betel Leaf Agroforest of Nongkwai village

Plant diversity:

In betel nut agroforest, a total of 136 plants were found associated with betel nut of which 57 trees, 18 shrubs and 40 herbs and in betel leaf agroforest a total of 159 plant species, 94 trees, 17 shrubs and 48 herbs were recorded. The plant species richness, density, basal area, Shannon–Weaver index and Shannon evenness for both agroforests are presented in Table 1. In betel nut agroforest dominant tree families included Euphorbiaceae (11), Moraceae (11) and Arecaceae (8) and Lauraceae (8) while in betel leaf agroforest dominant tree families included Euphorbiaceae (12 species) Lauraceae (12 species) and Moraceae (8 species).

Table 1. Diversity and community characteristics of plant species in betel nut agroforest and betel leaf Agroforest of south Meghalaya

Parameter	Betel nut agroforest			Betel leaf agroforest		
	Tree	Shrub	Herb	Tree	Shrub	Herb
Sampling size (ha)	0.4	0.05	0.01	0.4	0.05	0.01
Number of families	31	14	27	41	13	31
Number of genera	57	18	38	78	21	42
Species richness	76	20	40	94	17	48
Density (ha^{-1})	1678	5680	62231	1788	7660	423688
Basal area (m^2ha^{-1})	59.90	-	-	50.06	-	-
Species evenness index (E)	0.53	0.95	0.91	0.90	0.45	0.95
Shannon diversity index (H')	3.11	2.86	3.36	4.10	2.70	3.68

Main uses of plants:

Based on the usage patterns, the plant species present in the betelnut agroforests were grouped into eleven broad categories viz., (1) timber divided into: high value timber (HVT) and low value timber (LVT), (2) fuelwood divided into: high value fuelwood (HVFW) and low value fuelwood (LVFW), (3) edible (E) divided into exotic and indigenous, (4) medicinal (M), (5) tool (T), (6) ornamental (O), (7) cash crop (CP), (8) craft (C), (9) no specific use (W), (10) spice (SP), (11) packing leaf (PC), (12) latex producing plant (L) and (13) thatch leaf (TH). For timber and fuelwood, based on the preference of the local people the plant species were further divided as high value for preferred plant species and low value for less preferred species. Edible plants included: fruit, vegetable and seed. Number of plant species base on usage patterns in both agroforest is given in Table 2.

Table 2. Number of plant species and their main uses in BLA in south Meghalaya

Main uses		Betel nut agroforest	Betel leaf agroforest
Timber	High value	10	10
	Low value	12	11
Fuelwood	High value	10	20
	Low value	23	31
Edible		18	15
Medicinal		18	17
Tool		3	6
Ornamental		3	5
Craft		1	2
Packing Leaf		1	1
Latex Producing Plant		1	1
No Specific Use		36	40
Total		**136**	**159**

Tree species with high IVI in betel leaf agroforest includes *Duabanga grandiflora*, *Sarcosperma griffithii* and *Ficus glomerata.* Population characteristics of ten most important tree species in betel leaf agroforest is given in Table 3.

Table 3. Population characteristics of ten most important tree species in betel nut agroforest and betel leaf Agroforest of south Meghalaya

A. Betel nut agroforest	Family	Frequency	Density	IVI
Cinnamomum tamala Fr. Nees.	Lauraceae	90.00	189	23.00
Artocarpus heterophyllus Ham.	Moraceae	65.00	111	15.13
Cedrela toona Roxb.	Meliaceae	27.50	30	5.37
Ficus gibbosa Blume.	Moraceae	17.50	21	3.52
Caryota mitis L.	Arecaceae	27.50	20	4.74
Cryptocarya andersoni King.	Lauraceae	22.50	14	3.72
*Aporosa dioica (*Roxb.) Muell. Arg.	Euphorbiaceae	17.50	12	2.98
Macaranga peltata (Roxb.)Muell.Arg.	Euphorbiaceae	17.50	11	2.90
Schima wallichii Choisy.	Theaceae	20.00	8	3.50
Toona ciliata Roem.	Ochnaceae	15.00	3	2.60
B. Betel leaf agroforest	**Family**	**Frequency**	**Density**	**IVI**
Sarcosperma griffithii Benth.	Sapotaceae	57.50	132	16.36
Ficus glomerata Roxb.	Moraceae	27.50	92	10.9
Wrightia tomentosa Roem & Sch.	Apocynaceae	32.50	76	8.19
Phoebe cooperiana U.N.Kanjilal ex A.Das.Nov.sp.	Lauraceae	30.00	70	8.70
Duabanga grandiflora (Roxb. Ex DC.) Walp.	Sonneratiaceae	32.50	58	32.78
Adenanthera pavonina L.	Mimosaceae	40.00	44	6.39
Artocarpus lakoocha Roxb.	Moraceae	40.00	36	7.01
Caryota urens L.	Arecaceae	27.50	26	6.85
Toona ciliata Roem.	Ochnaceae	32.50	26	6.86
Ficus benjavina L. var.comosa Kurtz.	Moraceae	7.50	12	10.51

DISCUSSION:

The betel nut agroforests harbour substantial plant diversity as the primary forests of south Meghalaya. For example the Shannon's diversity index of betel nut agroforest showed 3.3 for trees, 2.8 for shrubs and 3.4 for herbs very similar to Shannon's diversity index of primary forests of south Meghalaya which was 3.9 for trees, 3.5 for shrubs and 3.0 for herbs (Tynsong 2009). It has been found that density of tree (1678 stem ha^{-1}) in betel nut agroforest was significantly lesser compared to average density of tree (2005 stem ha^{-1}) in natural forests of south Meghalaya (Tynsong 2009). Lesser in tree density in the betel nut agroforests may be due the fact that a number of trees were felled during the conversion of natural forests to betel nut agroforests. However, a reverse trend was observed in the density of herb (62231 stem ha^{-1}) in betel nut agroforest and in natural forest the density of herb (2925 stem ha^{-1}) (Tynsong 2009). The density of herb was more in the betel nut agroforests mainly because of lower tree density, thus providing ample sunlight for light demanding herbaceous plants to grow. Species composition in both the forests is more or less similar. In betel nut agroforest of south Meghalaya, the plant genus was represented by multiple species contributed to high species richness and diversity of forests (Aiba and Kitayama 1999). High species richness shows that the traditional agroforestry systems are suitable land use for the edapho-climatic conditions prevailing in the area for conservation of biodiversity in the prevailing edapho-climatic conditions. Species richness may be also attributed to the similar topography, soil and climatic condition by both forest types (Jamir *et al*. 2006). It is difficult to explain the species richness of betel nut agroforests of south Meghalaya, it seemed that favorable climatic condition, unique topography and deliberate management of plant species over a long period of time have played major role in making the community rich in diversity of plants. Growing betel nut along with diversified native plant species contributes to biodiversity conservation within agricultural landscapes, complementing conservation in protected areas (Schroth *et al*. 2004). People of rural Meghalaya depend considerably on forest resource base for their subsistence as a result it causes disturbance on forest ecosystem of the area (Ramakrishnan 1985; Gangwar and Ramakrishnan 1990). Betel nut agroforest can play a role in conservation strategies in fragmented landscapes by providing habitat and resources for plant and animal species and by maintaining connectivity between forest areas. The high percentage of useful (including exotic) plant species in betel nut agroforest reflect the fact that farmers actively retain or introduce useful plant species into the betel nut agroforest. The preference for useful plant species is understandable in the context of rural people poor of Meghalaya depend on plant product for food, shelter, medicine and fuelwood (Tiwari *et al*. 2004). The presence of other non-betel nut trees in betel nut agroforest helps farmers achieve their basic needs of food, health, energy and housing. Tree species were managed mainly for timber, fuelwood and edible purposes. Tree species which is preferred by local people for timber in betel nut agroforest include: *Artocarpus heterophyllus, Cedrela toona, Cryptocarya andersoni, Schima wallichii* and *Aporosa dioica*, the prefer fuelwood tree species include: *Macaranga denticulata, Macaranga hypoleuca, Macaranga peltata, Quercus dealbata* and *Quercus lanceofolia* and important tree species which were managed for edible purposes included native species like *Aporosa aurea*, *Gynocardia odorata, Garcinia anomala, Garcinia spicata* and an exotic species like *Litchi chinensis*, *Cocos nucifera* and *Mangifera indica.* The important Non-Timber Forest product species managed in betel nut agroforest of south Meghalaya includes *Cinnamomum tamala*, *Phrynium capitatum* and *Piper peepuloides*.

Similarly it is observed that betel leaf agroforests harbour substantial plant diversity. A comparison between the tree species richness of betel leaf agroforest of south Meghalaya with other agroforestry systems shows that tree diversity of betel leaf agroforest was significantly higher (94 tree species) than cocoa agroforest in southern Cameroon (21 tree species), betel leaf agroforestry in Bangladesh (61 tree species) (Nath et al. 2003) and betel nut agroforest of south Meghalaya (83 tree species) (Tynsong and Tiwari 2010) but lower than the Coffee farms in Veracruz, Mexico (Lopez-Gomez et al. 2008). Species richness for herb, betel leaf agroforest of south Meghalaya (48 species) was similar to cocoa agroforest of south Cameron (48 herb species) (Sonwa et al. 2007) and slightly higher than the betel nut agroforest of South Meghalaya (41 herb species) (Tynsong and Tiwari 2010). Tree species in betel leaf agroforest are more diverse as compared to traditional agroforests of Dellomenna District, Southeastern Ethiopia (H'=2.53 to 2.73) (Molla and Kewessa 2015), homegarden of Thailand (H'= 0.9 to 2.7) (Gajaseni and Gajaseni 1999) and traditional agroforests of Kerala in India (H'=1.12 to 3) (Kumar et al. 1994). Further, tree basal area of betel leaf agroforest of south Meghalaya in comparison with other agroforestry systems, had higher tree basal area. For example, in cocoa agroforest and mixed food crops agroforest in Southeastern Ghana basal area was recorded at 8.4 m^2ha^{-1} and 8.2 m^2ha^{-1} respectively (Asase and Tetteh 2010). It was also higher than cocoa plantations in Indonesia (11.9 to 20.5 m^2/ha) (Merijn et al. 2007) and cocoa plantations in the South province of Cameroon (29.7 to 42.6 m^2/ha) (van Gemerden 2004). Our results suggest that a better stock of forest tree species were maintained in betel leaf agroforest comparable to natural forest of the area. We also observed that few tree species such as *Trema polytoria, Macaranga denticulata, Macaranga peltata, Adenanthera pavonina, Ficus roxburghii* and *Wrightia tomentosa* were found only in betel leaf agroforest. Furthermore, the light-demanding second story tree species such as *Trema polytoria,*

Macaranga denticulata and *Macaranga peltata* grow luxuriantly in betel leaf agroforest. Higher herb species diversity in betel leaf agroforest may be attributed to the fact that it was dominated by light-demanding plants, specifically those belonging to Asteraceae, Rubiaceae and Poaceae. Even though in betel leaf agroforest all tree species were maintained as supporting trees, we observed that high percentage of economically useful plant species are retained for the purpose. The preference for multipurpose tree species is understandable in the context that the owners of the agroforests depend on such plants for timber, food, medicine and fuelwood (Tiwari et al. 2004). Motiur et al. (2006) also found that agroforests in Bangladesh supply important forest products like fruit, fuelwood, timber and bamboo to meet household demands. Tree species besides functioning as supporting trees, were maintained mainly for timber, fuelwood and edible purposes. Tree species which are preferred by local people for timber include *Artocarpus heterophyllus, Cedrela toona, Duabanga grandiflora* and *Schima wallichii.* While most preferred fuelwood tree species include *Macaranga denticulata, Macaranga hypoleuca, Macaranga peltata, Quercus dealbata* and *Quercus lanceofolia.* Important tree species which yield edible fruits include *Artocarpus heterophyllus, Cinnamomum tamala, Citrus macroptera, Gynocardia odorata* and *Baccuarea sapida.* No introduced/exotic species was maintained by local people in betel leaf agroforests. Farmers continue to rely on herbal medicines for treatment of their ailments. Traditional health care based on folk medicines is widespread and popular in south Meghalaya. The tribal communities are very knowledgeable about the medicinal plants and depend on the herbal product for treatment of most of their ailments (Tiwari et al. 2004). Thus these manmade ecosystems serve the purpose of biodiversity conservation comparable to natural forest ecosystems while providing goods and services to the local inhabitants.

CONCLUSION:

This study illustrates the multiple purposes served by traditionally conserved agroforest of south Meghalaya. We found many potentially valuable NTFP and timber species from the local forest flora grow well in the two agroforests. The agroforests harbour plant diversity comparable to the natural forests and provide habitat for endemic and rare plant and animal species. The study concludes that traditionally managed agroforests of south Meghalaya are best suited land use practice with minimal impact on plant diversity and forest community structure.

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