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Vegetation Regeneration in Formerly degraded Hilly areas of Rwampara, South Western Uganda

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Abstract

Rwampara hills located in South Western Uganda have long been subjected to intensive degradation due to increased human activities. The hills have been left bare as a result of vegetation clearing for agricultural land, charcoal burning and grazing. In 1998, the National Environmental Management Authority (NEMA) attempted to restore the degraded hilly areas with the aim of establishing the restoration potential. With the cooperation of the local people, NEMA set aside some parts of the hills to allow natural regeneration, while another parts were planted with exotic tree species mainly Eucalyptus spp and Pinus patula. This paper presents findings of an assessment on the level of indigenous vegetation regeneration in the three zones namely; restored, planted and areas undergoing degradation due to grazing. The indigenous vegetation was sampled using nested quadrats set along line transects. The results indicate that species richness was different among the three habitat types with the highest number (17 species) recorded in the degraded (grazing) area, followed by the restored area (12 species) and the plantation had the least (10 species). Species density was highest in the restored zone (289.83/ha) and least (80.2/ha) in the plantation zone. The most common indigenous tree species regenerating in all the three study zones were; Olea europaea subsp. africana, Albizia adiathifolia and Markhamia lutea

Keywords: Degraded hills, vegetation regeneration, western uganda.

Introduction

Forest clearing, forest degradation through human disturbance and the deterioration of land productivity due to inappropriate agricultural practices is a major problem in the tropics. Increased human activities such as agriculture, grazing, firewood collection and charcoal burning aimed at improving livelihoods has caused severe land degradation of marginal lands, especially in hilly areas of western Uganda. Population increase and economic growth are primarily the driving forces behind degradation of these marginal lands[1].

The Rwampara hills in western Uganda have a long history of land degradation. Past land use patterns and disturbance regimes have had a profound effect on the abundance, distribution and diversity of vegetation in the area. Due to severe effects of degradation, the area has become prone to agents of erosion. In 1998, the National Environment Management Authority (NEMA) initiated a program to restore the degraded ecosystem of Rwampara hills, with an aim of curbing soil erosion and increase its biological productivity and, local economic benefits and environmental services. Some local farmers volunteered portions of their land for the restoration purpose. These portions were set to regenerate naturally, while other parts were planted with eucalyptus and pine. This paper presents the vegetation regime after a decade of vegetation restoration in the degraded areas of Rwampara hills in western Uganda.

Material and Methods

Study area: Mbarara district in Western Uganda comprises of Rwampara County. The district is located at Latitude:-0.6132; Longitude: 30.6582 (figure-1). The landscape consists of rolling hills intercepted by long, but shallow valleys with wetlands occurring in the valleys. According to the National Population and Housing Census of 2002, Rwampara County has a population of 132,802 and a land area of 659.8 km^2. The area receives a moderate rainfall throughout the year with an average rainfall of 1200m and temperatures ranging from 17^{0}C to 30^{0}C. Two rainy seasons occur in the area from March to May and September to December, while dry spells are experienced from December to February and June to August. The relative humidity ranges from 80-90% in the mornings and 48-60% in the evenings throughout the year. The vegetation in the area consists of ever green and broad leaves, characteristics of medium attitude tropical rain forests. The current vegetation is dominated by indigenous and exotic tree species. The land has been subjected to intensive agricultural activities, mainly banana cultivation and livestock farming.

Vegetation sampling: Vegetation sampling was conducted in the three zones namely; degraded, restored and plantation zones. A stratified random sampling method was applied within the three zones. The principle of stratification was that the vegetation of the area under investigation was divided up before samples are chosen on the basis of major and usually obvious variations within the habitat[2]. The reason for this method of stratification was to sample zones of vegetation subject to different gradients and management regimes.

The vegetation was sampled using nested quadrates set along line transects[2]. The transect lines were set in the three vegetation zones namely; restored zone, degraded zone and plantation zones. A total of 12 line transects, each measuring 100m long were positioned in such a way that they ran from the bottom of the hill to the top, so as to sample different vegetation starata. Systematic sampling which involved the location of nested sampling points at regular intervals. In each line transect, a series of nested plots were established in an alternating left and right[3,4]. A series of 15m x15m plots were set up at regular intervals of 20m apart using a measuring tape. Within each plot of 15m x 15m, a series of nested quadrat measuring 10m x 10m, followed by 5m x 5m and 2m x 2m were established to enumerate trees of different size classes that occupy different vegetation strata. Large tree size class measuring ≥ 15cm dbh (1.3m) were sampled in 15m x 15m plot, followed by small trees (dbh 10cm -< 15cm) sampled in 10m x 10m plots. Poles (5cm – <10cm, dbh) and saplings (dbh 2cm- <5cm) were sampled in 5m x 5m plot, whereas seedlings (< 2cm) were sampled from 1m x 1m plots.

Species diversity and Richness: Plant species diversity was calculated from Shannon's diversity index, $H = -\sum p_i \log_e p_i$, where Pi = is the proportion of each species in the sample[5]. Species richness, R was calculated as measure of the number of species found in a sample or zone.

Important Value Index (IVI): To obtain importance value index, the frequency, density, and dominance of each species was determined in each zone. Then, IVI was calculated as;
Importance value = Relative frequency + Relative density + Relative dominance

Where; **Relative frequency:** Number of occurrences of one plant species as a percentage of the total number of occurrences of all species.

Relative density: Number of individuals of one species as a percentage of the total number of individuals of all species

Relative basal area (dominance): Total basal area of one species as a percentage of the total basal area of all species.

Absolute density: This was determined by summing up the number of individuals found in each plot and divide by the number of plots.

Average species density = (density in plot 1) + (density in plot 2) + (density in plot X) /Total number of plots.

Results and Discussion

Species richness and diversity: Species richness and diversity indices of different diameter size classes in the three vegetation zones are presented in table-1. The results show that in the restored area, species richness ranged from 1 species for large tree size class ≥ 15cm dbh to 12 species for seedlings and poles (table-1). Similarly in the degraded area, species richness ranged from 1 species for large trees to 12 species for seedlings and poles. However, in the plantation zone, the highest number of species (10) was recorded for seedlings and none for small trees and large trees.

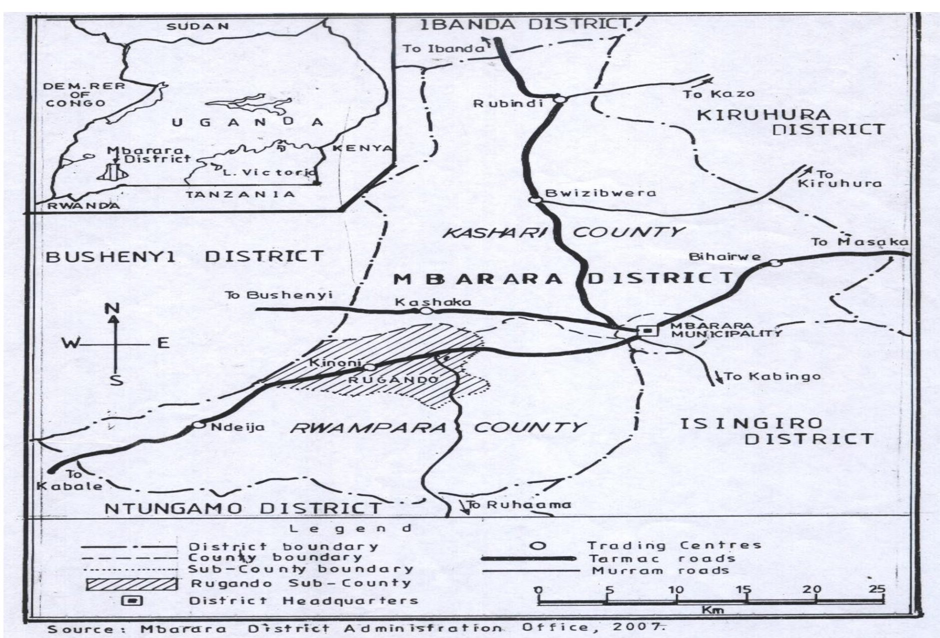

Figure-1
The study area in Rwampara County, South Western Uganda

The diversity index, H^1 of restored zone was highest (1.89) in saplings (2-< 5cm dbh) followed by seedlings (1.85) and lowest (0.00) in large trees (≥15cm, dbh), while in the degraded zone, the H^1 values ranged from 1.78 for poles (5-< 10cm, dbh) to 2.51 for seedlings (<2cm dbh). In the plantation zone the diversity index ranged from 1.68 to 2.07. Among the three vegetation zones, the degraded zone is more diverse (2.51) for saplings than the restored (1.89) and plantation (1.68). Generally, the seedlings (dbh <2cm) recorded the highest diversity indices, and large trees had the least diversity in all the three study sites.

Tree densities (No/ha) of different size classes: The log density stand curves of different size-classes in plantation, restored and degraded zones are presented in figure-2. There was a general decrease in log density for all the tree size classes in all the three habitats from seedlings to large trees. In the restored and degraded areas, the log density decrease was gradual, while in the plantation zone, the log density decreased sharply to zero at poles.

Absolute density of tree species in different study zones: The absolute density (No/ha) of tree species recorded in degraded, restored and plantation zones are presented in table-3. *Markhamia lutea* (had the highest density (1076/ha) in the restored zone followed by *Albizia adiathifolia* (705/ha) and *Olea europaea subsp. africana* (600/ha). Within the degraded zone, *Tetrochidium didymostemon* had the highest density (64/ha) followed by *Senna didymobotrya* (957/ha) and *Cordia africana* (55/ha). In the plantation zone, *Olea europaea subsp. africana* had the highest density (190/ha) followed by *Albizia adiathifolia* (17/ha) and *Solanecio manii* (117/ha). Three species namely; *Olea europaea subsp. african, Albizia adiathifolia* and *Markhamia lutea* occurred in the three zones with *Markhamia lutea* contributing the highest density (38/ha) in the restored zone, while *Albizia adiathifolia* had the least density (7/ha) recorded in the degraded zone. Generally the restored zone had the highest tree density compared to the plantation and degraded zones (H=17.12, df=2, P=0.000)

Table-1
Species richness (R) and Shannon Diversity Indices (H) of trees of different size-classes recorded in Restored, Degraded and plantation zones

Study site	Diversity indices	Diameter size-classes (dbh)				
		Seedlings (<2cm)	Sapling (2-< 5cm)	Poles (5-<10cm)	Small tree (10-<15cm)	Large trees (≥15cm)
Restored	R	12	12	6	4	1
	H	1.85	1.89	1.15	1.09	0.00
Degraded	R	12	12	7	8	1
	H	2.26	2.51	1.78	1.99	0.00
Plantation	R	10	7	1	0	0
	H	2.07	1.68	0.00	0.00	0.00

* ***R***= *Species richness,* ***H*** = *Diversity index*

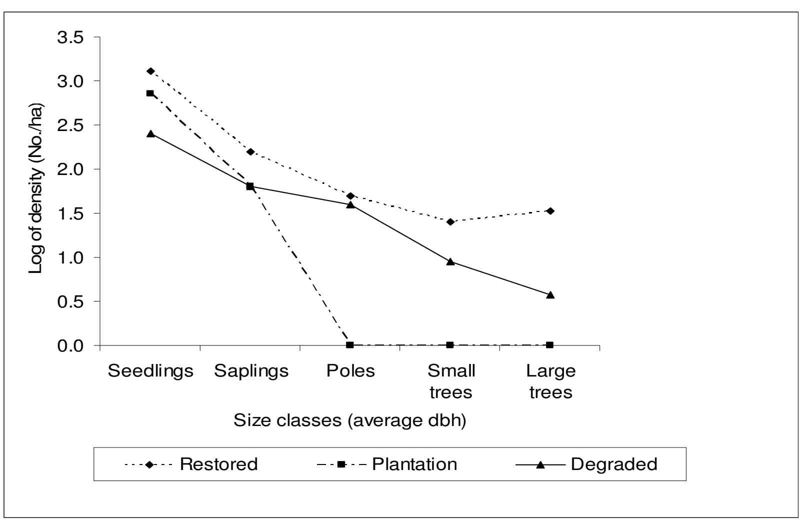

Figure-2
Species area curves showing a cumulative number of plant species recorded in the restored, degraded and plantation zones
Table-2

Absolute densities (No/ha) recorded in the Restored, Degraded and Plantation Zones

Species	Restored Zone	Degraded Zone	Plantation zone
Olea europaea subsp. Africana	600	12	190
Albizia adiathifolia (Schumach.) W.F. Wight	705	7	162
Markhamia lutea (Benth.) K. Schum	1076	38	110
Syzygium cordatum Hochst.ex Krauss	112	-	76
Acacia hockii De Wild	46	-	-
Peddiea fischeri Engl.	219	-	-
Pittosporum spathicalyx De Wild.	129	-	45
Myriathus holstii Engl.	205	-	-
Bridelia micrantha (Hochst.) Baill	76	-	-
Solanecio manii (Hook.f.) C.Jeffery	217	-	117
Allophylus macrobotrys Gilg.	60	-	-
Olea welwitschii (Knobl.) Gilgand Schellenb	33	-	-
Sapiu m ellipticum (Hochst. Ex Krauss) Pax	-	31	-
Albizia coriaria Welw.ex Oliv	-	45	-
*Senna didymobotrya (*Fresen.)Irwin and Barneby	-	57	-
Antiaris toxicoria (Rump h.ex Pers.) Lesch.	-	-	29
Polyscias fulva (Hiern) Harms	-	-	21
Cyphomandra batacea F l. Neotrop.Monogr.	-	-	7
Macaranga kilimandscharica Pax	-	-	45
Senna bicapsularis (L.) Roxb	-	21	-
Maes lanceolata Forsk.	-	2	-
Albizia gumefera Welw.ex Oliv	-	26	-
Cordia Africana Burm.f.	-	55	-
Vernonia amygdalina Del.	-	52	-
Erythrina abyssinica Lam. Ex DC	-	48	-
Ficus natelensis Hochst.	-	17	-
Acanthus pubescens (Thomson ex Oliv.) Engl.	-	19	-
Tetrochidiumdidymostemon (Baill.) Pax and K.Hoffm.	-	64	-
Diospyros abyssinica (Hiern) F. White	-	48	-
Croton sylvaticus Hochst.	-	43	-
Ficus natelensis Hochst.		17	-
Acanthus pubescens (Thomson ex Oliv.) Eng	-	19	-
Tetrochidiumdidymostemon (Baill.) Pax and K.Hoffm	-	64	-
Diospyros abyssinica (Hiern) F. White	-	48	-
Croton sylvaticus Hochst.		43	
Total	289.83	34.41	80.2

Principal component scatter diagram in figure-3 was used to explain the species density in the restored, plantation and degraded zone. As you move towards the right hand side, there is less disturbance and hence high plant densities while as you move towards the left hand side, there is high disturbance and hence lower densities but many varieties of plant species.

Importance Value Indices (IVI) for tree species: Importance value indices (IVI) calculated from relative densities, relative frequency and relative dominance for all the tree species recorded in the natural, degraded and plantation zones are presented in table-3. In restored zone, *Olea europaea subsp. Africana* had the highest importance value (271.2) followed by *Albizia adiathifolia* (147.1) and *Markhamia lutea* (105.4). Whereas in the degraded zone, *Albizia adiathifolia* had the highest IVI (127.1) followed by *Croton sylvaticus* (96.8) and *Cordia Africana* (50.3), while in the plantation, *Olea europaea subsp. africana* had the highest IVI (222.1) followed by *Albizia adiathifolia* (66.5) and Markhamia *lutea* (47.3).

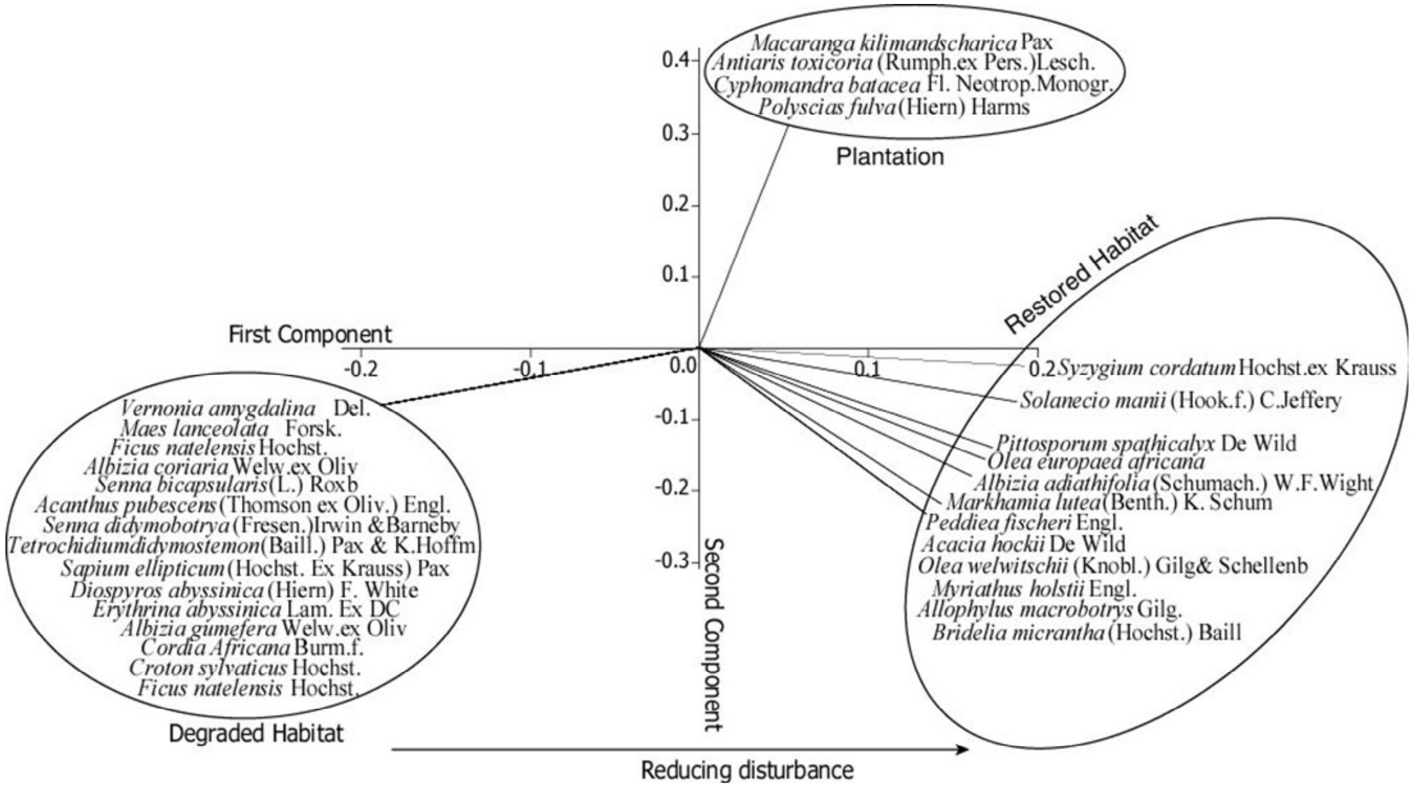

Figure-3
A principal component analysis (PCA) diagrams showing the absolute densities of plant species in the study area

Discussion: The higher values of species richness recorded in the degraded area in comparison with restored and plantation zones are an indication of high levels of regeneration following disturbance in the degraded hills. The study also indicated that following disturbance, re-growth of new species, which are either from the soil seed store or are dispersed into the site from the outside, occurred efficiently. Most disturbances create highly heterogeneous habitats that recruit different species and play out different growth scenarios[6]. Some of the agents of disturbances in the study area included fires, overgrazing and cultivation and this caused the creation of gaps. Forests are subject to a number of naturally occurring disturbances[7] that produce a range of different sized gaps (spaces). This led to creation of space for new tree species.

The lower species richness observed in the restored zone compared to the degraded zone could be due to the slow regeneration rates of some species. Fire significantly affected species composition and decreased species richness[8] because most species had either their re-sprouting ability or seed germination inhibited by fire and this could be the case in the restored area. Restoration in the area that begun 10 years back after several agents of disturbances consists of mostly secondary species. Species regenerated from seeds but primary species owed their presence in regeneration to their ability to reproduce vegetatively. Some seeds require fires to break their dormancy and if the rains come soon after, this enables regeneration. Species richness was low in restored zone because some species like *Olea europea subsp. africana* have a slow growth rate. However, the low number of species obtained in the plantation zone could be attributed to suppression of indigenous trees by the eucalyptus trees. Eucalyptus suppresses the growth of native species[9], hence the reason for low species richness.

The degraded zone was more diverse and showed higher equitability than other areas. The high diversity of indigenous tree species in the lower size classes (seedlings and saplings) for all the three study sites is an indicator of regeneration. Large size classes showed lower diversity and density indicating low survival rate of seedlings into the large size class. The younger size class is usually numerous[9,10] compared to the older size class. This is due to the fact that mortality rate is high in early stages of life because of predation, desiccation and competition as well as removal by human activities.

On tropical mainland, more than 90% of all tree species have more than 50% of their seeds killed by animals and fungi between fruit set and seed germination[11]. Some seeds land in places where the seedlings have no chance of survival and so a few may reach maturity. On the other hand, lower number of large trees recorded in the degraded area could probably be due to selective removal of some trees during harvesting, while the low diversity of large size class trees in the restored area could be due to dominance caused by some species.

Tree species in a tropical rainforest display much variation in timing, duration and frequency of flowering[12] and this could be the case in Rwampara. Species vary considerably in duration of flowering which extends from a few days in some species to several months in others. Lower diversity of large size classes in the plantation zone could be attributed to suppression by eucalyptus and *Pinus patula* in the area. It could be that the gaps are small and so the shade intolerant species begin to die as soon as maturation starts.

Rwampara hilly areas have been influenced by human activities such as agriculture and fire. High abundance of some tree species suggests a form of dispersal and plant utilization. For instance, *Olea europea subsp. africana, Markhamia lutea and Tetrochidium didymostemon* were highly abundant in the restored, plantation and degraded zones respectively. Plants become established either from the seedling pool, soil seed store, vegetative re-growth and dispersed seeds. *Olea europea subsp. africana* can regenerate from wildings and seedlings and *Markhamia lutea* from wildings, seedlings and cuttings.

Several tree species like *Sampium ellipticum, Markhamia lutea, Peddiea fischeri* and *Pittosporum spathicalyx*. had several seed or fruit dispersal mechanisms and they may also regenerate from coppice or root suckers apart from wildlings, direct sowing and seedlings.

Olea europea subsp. africana and *Albizia adiathifolia* had the lowest densities in the degraded area compared to the restored and plantation areas. *Olea europea subsp. africana* is highly used by the local community for firewood, charcoal, medicine, poles, walking sticks, tool handles and environmental purposes such as soil conservation and this could be the reason why it is low in the degraded area. *Olea europea subsp. africana* is also a slow growing tree so once it is harvested; it takes long to re-grow[13]. Currently the restored and plantation zones are restricted from harvesting.

Maesa lanceolata had the lowest density in the degraded area than other species yet it is a fast growing tree. This could be attributed to the rate it is harvested since the local people use it to treat diseases like ulcers, diarrhoea and febrile convulsions in children. Some species like *Olea europea subsp. africana* and *Peddiea fischeri* are slow growing yet are highly diverse in restored and plantation zones. This could be because both restored and plantation zones are restricted from harvesting, hence allowing them time to regenerate.

Polyscias fulva had the lowest density in the plantation zone yet it is a fast growing tree species. The reason for this is that it is highly harvested for firewood, timber, and bee hive making. *Polyscias fulva* is a light demanding species[14] but being in the plantation zone it is shedded and so its growth is suppressed.

Vegetation sampling from the study indicated a high number of indigenous tree species in the lower size-class in all the study sites. Large size class trees had low densities and this could be due to the low survival rate of seedlings into large trees. Size class distribution of tree diameters of tropical forests show a reverse J-shape or negative exponential distribution[15, 16] similar to the results of this study.

The high densities of seedlings of exotic species are an indication of higher initial recruitment in the lower size class[17]. The fewer numbers of large size-class could be due to the high rate of larger tree harvesting by local people and a similar trend of size class distribution was observed in Mgahinga Gorilla National Park[9]. The high densities of seedlings in all the three zones indicated the importance of the presence of propagules in determining the composition of early successional communities and their establishment.

Conclusion

The regeneration pattern of the indigenous tree species in Rwampara hills varied in each study site because of human disturbance which could have influenced seed dispersal mechanism, fruiting, germination and regeneration of tree species. The indigenous and exotic trees are very essential to the rural people and this was recognized from the resources harvested.

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