Benefits or losses from tree clearing in pasture systems of central Queensland, Australia?

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Abstract

Broadscale tree clearing has been widespread in Queensland as landholders try to increase pasture production. The recent government policies aim to stop broadscale clearing by 2006, but the debate over the opportunity cost of the regulatory controls continues. Previous studies of the pasture production gains following clearing have identified key improvements, which can be expected to increase livestock production. These studies have all been focused at relatively short term impacts (less than 10 years), raising questions of whether pasture production gains are sustainable over the longer term.

The key focus of the research reported in this paper was to determine if pasture production gains following clearing were maintained over the longer term. For this, the pasture yield and the ecological effects of tree clearing over three different time periods for three different vegetation communities in central Queensland. The results indicate that pasture production increases post-clearing, but then declines over the longer term (more than 30 years). A bioeconomic model applied to develop scenarios for pasture production over the 50 years of time frame of clearing, also suggested a decline in pasture yield with age of clearing based on the yearly average increase estimated from the old (30 years) to 50 years of age clearing. Although, the cleared pastures could be economically beneficially as predicted in bioeconomic model, however, it is difficult to predict how the change in ecosystem functions in old pastures (> 30 years of clearing), by implication, affect pasture yield. The opportunity cost of clearing to achieve production gains in terms of loss of ecosystem functions and their implication for future production gains, are discussed.

Key words: Tree clearing, pasture production, livestock production, ecosystem functions.

Introduction

Broadscale tree clearing has been widespread in Queensland grazing systems as landholders try to increase pasture production. In the 1999-2001 period, an average of 577,000 hectares were cleared each year, with 94% developed for the purposes of improving pastures (Department of Natural Resources and Mines 2003). Cleared land is mostly sown to exotic grass species such as buffel grass (*Cenchrus ciliaris* L.) following raking and/or burning of wooden logs. This grass is very dominant, so pastures effectively become monocultures.

Most studies to date (Burrows, 1993; Burrows et al. 1999; Scanlan and Burrows, 1990) have highlighted the production gains from clearing, but these were limited to <10 years of age of cleared pastures (Scanlan, 2002), and without considering the associated loss of ecological services.

Clearing trees to develop land for pastoral and agricultural systems has historically been favoured under different government policies until 1985 (Boulter et al., 2000). Since the 1990s, there has been increasing levels of control by the State Government over clearing activities (Rolfe 2000), culminating in controls on freehold land introduced in 2004. This placed a cap on the total area to be cleared, with all clearing activities to be completed by 2006. The debate over clearing has focused on production versus conservation outcomes, and it is unclear how economical it is to clear vegetation on more marginal soils, particularly when long term ecological impacts are considered (Rolfe 2000). It is also unclear whether clearing activities trigger changes in ecosystem functioning that could increase the risk of future production losses.

The research reported in this paper is aimed at identifying the productive and ecological impacts of clearing over a longer time period in the central Queensland region. Three major woodland communities i.e. Brigalow scrubs (*Acacia harpophylla*), Box woodlands (*Eucalyptus populnea*) and Ironbark woodlands (*Eucalyptus melanophloia*) were selected on one property to quantify the impacts of clearing on pasture production and composition, soil properties, and litter production. The impacts were measured over time at recent (<5 years), medium (11-13years) and old (>30 years)) age of cleared pastures in comparison to their uncleared (intact) woodland pastures for each tree community. The losses and benefits from clearing in pasture development are further used in a simple bio-economic model to assess the net commercial benefits of clearing activities.

The results provide information about the net private benefits of clearing activities after potential declines are assessed over the longer term. Only the potential private costs of clearing activities are included in the analysis. The public costs of clearing activities (largely associated with biodiversity losses) are discussed in Blamey et al. (2000) and Rolfe (2000a). To assess the overall value of tree clearing activities to the community, the net private benefits of clearing activities would need to be compared to the net public costs resulting from the clearing activities (Rolfe 2000b).

Impacts of Tree Clearing on Ecosystem Functions

Boulter et al. (2000) provide an overview of grass-tree interactions, and on the impact of clearing on complex ecosystem functions. A key concern is that those impacts may counter production gains from clearing. Dryland salinity is a classic example of where clearing has impacted on ecosystem functions and generated longer term production losses. As Pannell (2004) shows, the bulk of production losses have occurred on the same properties where clearing took place, meaning that clearing decisions have been sub-optimal for the farmers involved.

It is important to consider ecosystem services from trees and their role in production, e.g. a stable environment due to their shade and litter, stable hydrological cycle, recycling of nutrients, and by providing substrate for various soil microbial activities that results in improved physical and chemical conditions of soil. Williams et al., (1993) suggested that clearing of trees disturbs the equilibrium of soil processes (nutrient recycling and decomposition). Reduced species diversity in cleared pasture systems could adversely affect the ecosystem function such as nutrient allocation (Tilman, *et al.* 1997). Similarly, changes in litter composition may lead to further changes in microbial communities and in return of nutrients to soil through litter decomposition (Kutsch and Dilly 1999; Vetaas, 1992). All these processes which result from change in vegetation structure from woodlands to open grasslands may lead to changes in soil pHw or soil microbial biomass (Sangha et al., 2005; Vetaas, 1992; Bruce et al., 2000). Introduction of exotic grass species such as C. ciliaris, and clearing of native vegetation may disturb the plant-soil relationship in cleared pasture systems.

The Central Queensland Case Study

Materials and methods

Paired sites of cleared and intact/uncleared woodlands for the three vegetation types were selected across three age groups of clearing i.e. recent (5 yr), medium (11-13 yr) and old (33 yr) on a property "Avocet" (30 km. south of Emerald) in central Queensland, Australia. Having all the sites on the one property meant that a number of other potentially confounding factors such as climatic factors and property management impacts were held constant.

Above-ground pasture biomass and pasture composition

At the centre of the selected 1 ha area at each site, a fenced plot of 10 m x 10 m (an exclosure to exclude cattle) was established to determine pasture above-ground biomass and composition. A quadrat size of 1 m x 1 m, derived from the stable number of species per unit area based upon preliminary analysis, was chosen. Measurements were taken from five randomly assigned quadrats located at different positions for March 2001, July 2001, November 2001 and March 2002. Plant samples from each quadrat were harvested just above-ground level, taken to the laboratory and dried at 60 ^{o}C for 48 hours to determine their biomass. The average quantity of pasture above-ground biomass for grazing was calculated over a 12 month period from these seasonal measurements. All types of plants in a quadrat were also identified to study the species composition.

Litter production

Litter production is an important indicator of ecosystem stability because it determines the amount of nutrients being recycled and available for future plant growth. In the experiment, litter production was measured at four monthly intervals at unfenced sites (each of one ha) using the paired-plot technique (Wiegert and Evans, 1964). On each occasion, three random quadrats of 1m x 1m were laid in three different directions. The average amount of litter produced over a year was computed from litter produced during different seasons.

Litter samples collected in March 2001 (without decomposition) from each site were thoroughly mixed, ground, and analysed for N (using CHN analyser) and P (using ICP).

Soil properties

Soil attributes are also important indicators of ecosystem stability, as the changes in soil parameters directly impact on pasture production. In the experiment, soil samples were taken (bulked for 8 cores per site) from unfenced sites (1 ha area) in January 2002 using a hydraulic soil rig. The samples were taken at different depths (0-5, 5-10, 10-20, 20-30 and 30-60 cm). Samples were processed to remove visible roots and pebbles, and analysed at the soil laboratories of Incitec Ltd (Brisbane) for soil organic carbon (SOC), soil pH_w and soil NO_3^- . To determine the microbial biomass of Carbon (SMB-C) and Nitrogen (SMB-N), samples were taken from the top 0-5 cm of soil in March 2002, and analysed using the chloroform fumigation extraction method (Vance et al., 1987) at the Natural Resource Sciences Laboratories (Department of Natural Resources, Mines and Energy, Indooroopilly, Brisbane, Queensland). Further details of methods used are reported in Sangha (2003).

Statistical analysis

To examine the integrated effect of studied attributes (pasture yield, species diversity, litter production, SOC, NO_3^-, pH_w and soil microbial biomass (C and N)) in cleared and uncleared pasture systems, data were analysed using a multivariate analysis technique i.e. canonical variates analysis (CVA). All the data were standardised for analysis.

The CVA was applied to determine the overall effect of clearing, as well as identifying the attribute(s) that differentiated between cleared and uncleared treatments in all tree communities. There were not enough replicates for cleared and uncleared treatments within a tree community to apply CVA within in each tree community, pooled data was used for all the cleared and uncleared treatments. The CVA analysis finds linear combinations of the original variables that maximize the ratio of between group to within-group variation where groups are cleared and uncleared treatments. Two canonical variates (CV1 and CV2) were considered to explain variation between treatments. The output from CVA presents an integrated impact of clearing in pasture systems.

Experimental Results: An integrated effect of studied ecological attributes on the stability of a pasture system

The combined effect of clearing on various attributes on a pasture system was determined with CVA (Canonical Variates Analysis). Two canonical variates (CV1) and (CV2) were selected for recent, medium, old cleared and uncleared treatments across all tree communities. The first canonical variate (CV1) distinguished the oldest cleared treatment from medium and recent cleared, and uncleared treatments (CV1 explained 90 per cent of variation among these treatments) (Figure 1). The difference in the state of pastures at the old age of clearing compared to other treatments was mainly due to the combined effect of soil NO_3^-, pasture biomass, litter production, species diversity and soil pH_w (Table 1). Comparatively greater values of positive loadings for these attributes than the others suggested that recent and medium cleared, and uncleared treatments had better soils with greater pasture biomass and litter production than that the old cleared treatments. The greater value of negative loading for pH_w demonstrated that pH_w was greater at the oldest clearing than at medium and recent cleared, and uncleared treatments (Table 1).

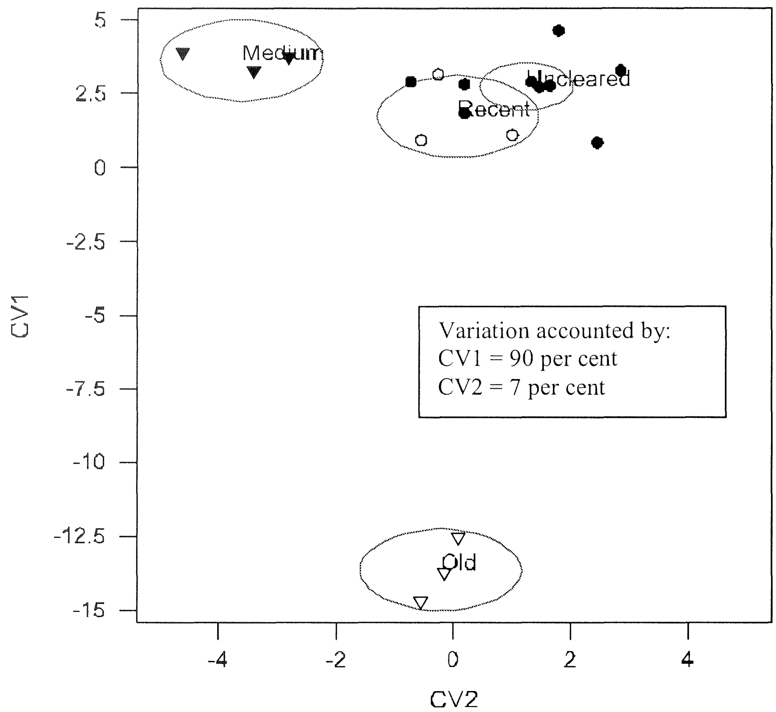

Figure 1. Relationship between first and second canonical variates for cleared (recent, medium and old) and uncleared treatments (with 95 per cent confidence regions around means).

A further 7 % of the variation between cleared and uncleared pasture systems was explained by CV2. CV2 showed that the medium cleared treatment was different to the recent and old cleared, and uncleared treatments (Figure 1). The species diversity and SMB-C and SMB-N had a greater influence (positive loadings) on CV2 than did the other attributes (Table 1). The greater values of negative loadings for pasture yield, than for example litter production and soil NO_3^-, explained the lower pasture biomass at old and recent clearing, and uncleared treatments compared to medium clearing (Table 1).

Table 1. Loading values for various variables from the canonical variate analysis for recent, medium and old cleared, and uncleared treatments.

Variables	Loading values for CV1	Loading values for CV2
Pasture biomass	3.60	-0.47
Species diversity	2.54	0.86
Litter production	3.40	-0.39
Soil organic carbon	-1.80	-0.07
Soil pH_w	-3.24	0.09
Soil NO_3^-	3.82	-0.27
Soil microbial biomass-C	1.86	0.25
Soil microbial biomass-N	0.72	0.55

The greater pasture yields at medium clearing was traded for losses in species diversity and some soil functions. The differentiation of results between different clearing ages indicates that post-clearing systems are not stable, and will deteriorate over time.

Modelling the Economic Implications

Assessment of economic benefits from clearing based on the extrapolation of initial pasture production gains is inappropriate as demonstrated in section 4. A key issue is whether landholders are particularly optimistic when making clearing decisions by assuming production gains are sustainable over the longer term. A second issue is whether different decisions would be made by landholders if they were better informed about the longer term impacts on ecosystem functioning and productivity that might result from clearing activities. To test these issues, some modelling of the economic outcomes of the clearing activities was undertaken.

An assumption was made that livestock production was only related to changes in pasture yield[1]. A relationship between dry matter consumption and weight gain for a 400 kilogram steer was assessed using the feed relationship reported by Minson and McDonald (1987). A 400 kilogram steer gaining 0.5 kilograms per day will need to consume an average of 7.52 kilograms of dry matter/day. Using the stocking rates on the property where the experiments were carried out, it has been estimated that 23.38 % of all dry matter produced above 500 kg/ha was consumed by cattle. The remainder of the feed may be consumed by kangaroos and other animals, burnt by fires or recycled into the soil. Using these estimates, the additional pasture biomass generated by clearing activities can be equated to changes in kilograms of livestock produced. This estimate can be multiplied by an average market price of $1.50/kg for cattle to convert the estimate into gross value of additional production.

A summary of expected values of production changes is shown in Figure 2. This confirms that there are increased returns from clearing in the shorter term, but these returns diminish in the longer term.

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[1] While this assumption simplifies the analysis, it may have the effect of understating the benefits of improved pastures, as these tend to have higher nutrient levels and faster rain-response patterns than native pastures.

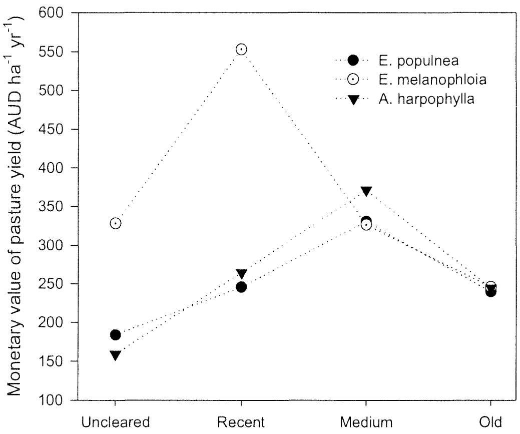

Figure 2. The monetary value of pasture yield produced at uncleared, recent, medium and old cleared sites for *E. populnea*, *E. melanophloia* and *A. harpophylla* communities.

However, to assess the present value of the increased production available from clearing, it is important to sum the expected returns over the longer time frame. This can be done by estimating the amount of pasture production each year for the foreseeable future (e.g. 50 years), converting that to the value of projected animal production, and summing the values over time.

In predicting the expected values of pasture production over time, four potential scenarios have been considered. The first is where landholders might assume that pasture production at recent time-since-clearing will stabilise, and remain constant into the future (Figure 3). The second is where pasture production is expected to be constant after the medium time-since-clearing point, while the third is where pasture production is expected to be constant after the older time-since-clearing point. The fourth scenario is where the reducing production from medium to old time-since-clearing is expected to continue into the future. The expected outcomes are shown in Figure 3. Scenario 4 appears more applicable (as evident in the present study that pasture yield declines till old age of clearing), thus raising the concerns for decline in pasture yield with age of clearing.

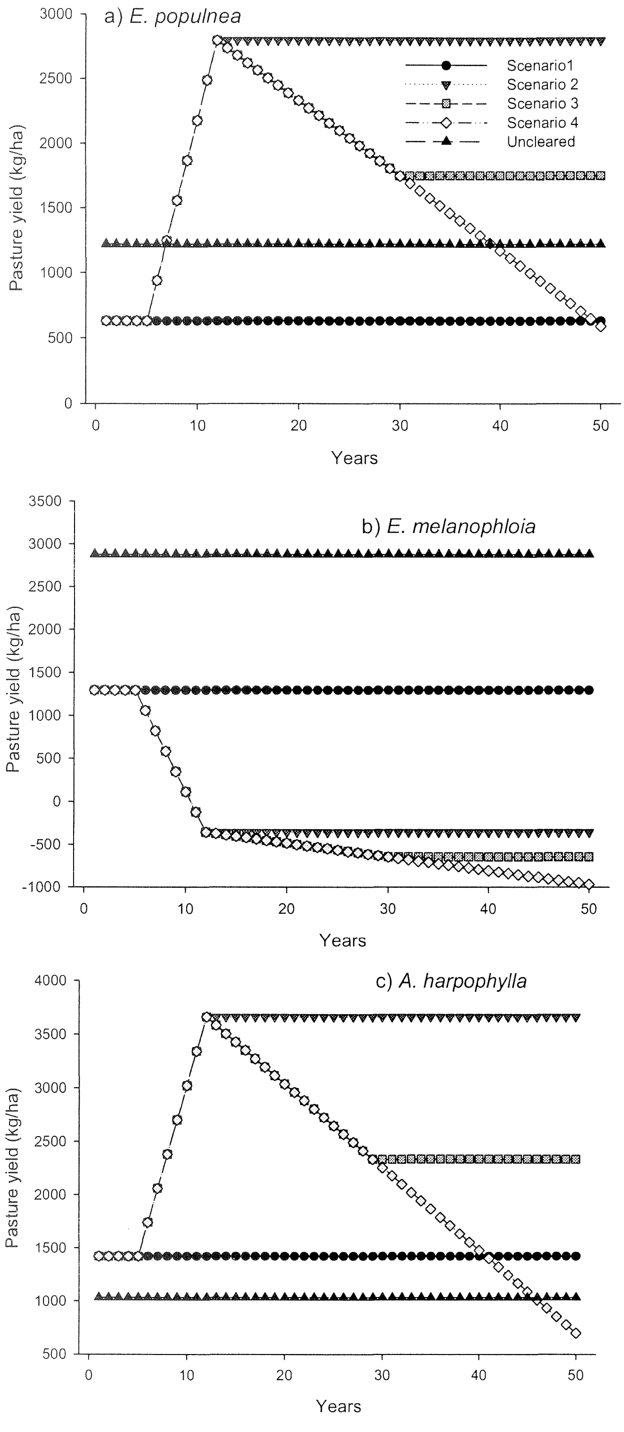

Figure 3. Four scenarios for cleared pasture systems for the average increase in pasture yield per year in relation to previous age of clearing (e.g. increase in pasture yield at recent clearing in relation to uncleared, at medium in relation to recent, and at old clearing in relation to medium clearing) over the 50 years of time-since-clearing:

1. Pasture yield stabilises at recent age of clearing;
2. Pasture yield stabilises at medium age of clearing;
3. Pasture yield stabilises at old age of clearing; and
4. Decline in pasture yield continues with age of clearing

for a) *E. populnea,* b) *E. melanophloia* and c) *A. harpophylla* communities.

* *Actual data are presented for pasture yield at uncleared sites.*

Expected values of additional livestock production have been simulated for a 50 year period by assuming that pasture production immediately moves to the recent age-since-clearing levels post clearing, and that other movements as per scenarios one to four are distributed evenly between the periods. An example of the annual returns estimated for these vegetation communities is shown in Figure 4, while results of the simulation exercise are summarised in Table 2.

Table 2. Discounted present values for additional cattle production resulting from clearing using three different discount rates.

Vegetation type	Discount rate	Scenario 1	Scenario 2	Scenario 3	Scenario 4
E. populnea	6%	247	761	648	623
E. populnea	8%	195	553	486	475
E. populnea	12%	94	179	173	173
E. melanophloia	6%	504	112	80	74
E. melanophloia	8%	399	126	107	104
E. melanophloia	12%	191	126	124	124
A. harpophylla	6%	554	1087	939	902
A. harpophylla	8%	438	809	722	704
A. harpophylla	12%	210	299	290	290

The results demonstrate that clearing do generate high returns. Given that the discounted cost of clearing and maintaining pastures is likely to be about $100/hectare, the results also indicate that clearing usually generates positive returns for landholders. The exception is ironbark woodlands, where clearing is likely to be unviable at the higher discount rates.

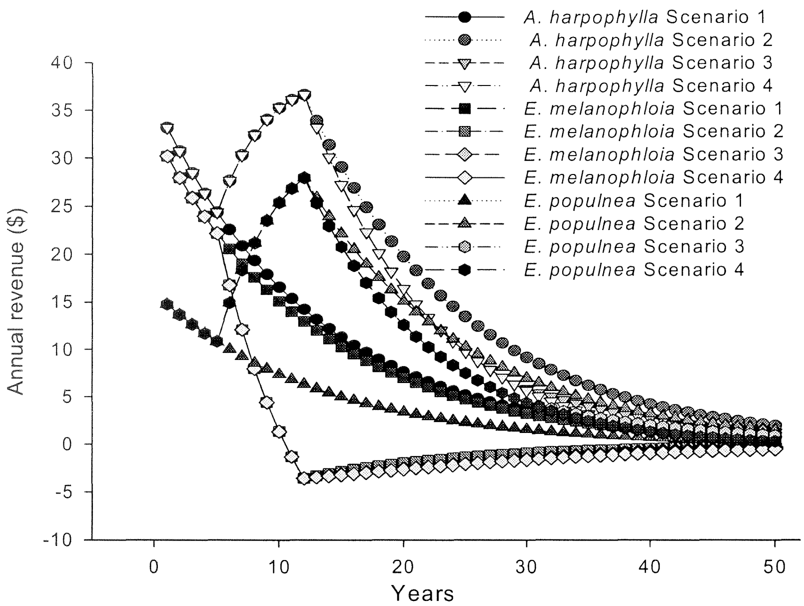

Figure 4. Annual returns post clearing predicted for *E. populnea, E. melanophloia* and *A. harpophylla* communities.

The results also demonstrate that negative impacts on ecosystem functioning have little impact on the gross returns from clearing. The discounting impact tends to trivialise those future problems. One implication is that landholders are acting rationally in continuing to clear trees, even if they know that ecosystem functions will be impacted. Another implication is that improving knowledge about those ecosystem impacts may not change behaviour, because the financial incentives will continue to weighted in favour of clearing.

Conclusions

In Queensland, the increase in pasture yield upon clearing has been demonstrated in earlier studies by Burrows, (1993), Burrows et al., (1999), and Scanlan and Burrows, (1990), and was also evident in the present study for the initial time of clearing. The results of the study show though that those increases may not be fully sustainable, and that there may be longer term declines in pasture production and ecosystem functions associated with clearing activities. The results vary between vegetation types, with the duration of production gains being shortest for *E. melanophloia* woodland. It was also notable that where this woodland had been cleared for more than 30 years, pasture production was lower than in the uncleared woodland areas.

Most importantly, the experiment results indicated that there were a range of losses in ecosystem functions associated with clearing activities. The key ecological tradeoffs associated with clearing activities appear to be:

- Declines in pasture plant diversity which may affect ecosystem stability;
- Reduced return of nutrients through litter decomposition, which can imbalance the nutrient cycle in cleared pastures compared to woodland pastures; and
- Changes in soil properties that could, by implication, affect the growth of pasture species over a longer term.

The modelling results for pasture yield, especially scenarios 3 and 4, suggested that the gains in pasture yield will decline with age of clearing. However, the modelling results for economic returns demonstrate that clearing does generate high returns in many vegetation communities, despite the potential impact of lost ecosystem services on pasture production. The discounting effect means that the size of future losses is small compared to productivity gains in the short term. The results also demonstrate that there are some vegetation types where there are likely to be net on-farm economic losses from clearing.

These results should also be viewed in a wider context. The case study reported in this research was in an area where dryland salinity is not expected to be a consequence of clearing. If dryland salinity were a consequence, the net on-farm benefits of clearing would be expected to be lower. As well, the economic modelling results are focused on providing a more accurate economic assessment of the net on-farm impacts of clearing activities. A broader economic assessment of clearing options would also need to assess community values for biodiversity losses and social impacts, as reported in Rolfe (2000a, 2000b).

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