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Multiple Land Use in Tropical Savannas: Concepts and Methods for Valuation

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Abstract: Tropical savannas are mainly used for grazing, mining, conservation or Indigenous activities. Over the past years, grazing has proven to be economically inefficient and has led to depletion of natural resources. This study attempts to develop a framework for multiple uses of land resources in savannas. For this, alternative land uses of savannas, other than grazing are identified and an outline of economic framework to estimate the total benefits from various land uses is presented. This study addresses the importance of synergies among various land uses at a landscape level. Economic viability of each land use is proposed to be verified to develop sustainable multiple land use systems that could deliver the maximum benefits to the society. Externalities, both positive and negative are considered in total estimation of benefits at a landscape scale. The positive effect of one land use on another can help to enhance the landscape value and to optimize the use of various natural resources for sustainable production gains.

Key words: Land wage, tropical sanvanas, methods for valuation

INTRODUCTION

Tropical savannas are open landscapes of grass with scattered trees, cover about 1.9 m km^2 area in the northern part of Australia. These are mainly used for grazing, with some mining and tourism activities and some areas with subsistence Indigenous land use. Questions were raised in the past about the economic efficiency and sustainable use of natural resources from grazing savannas[1]. Economic returns from grazing are even less during drought (a common phenomenon in tropical Australia, at least for once in every 10 years). Poor, old soils coupled with highly irregular rainfall and extended dry seasons are the main reasons for grazing to be an economically inefficient land use[2]. Mismanagement or over use of natural resources to maximize benefits from grazing land further led to ecological problems in the region.

The economic inefficiency and depletion of natural resources with grazing in savannas have raised increasing interest in their alternative uses. The need for alternative land uses options of savannas was addressed in the 12th Biennial Conference 'the multiplicity of changes in use of rangelands' organised by the Australian Rangeland Society (Kalgoorlie, WA)[3].

Tropical savannas benefit the local, national and global community through various use and non-use values. The local communities are benefited for employment from tourism, grazing or mining and national and global communities for obtaining knowledge of biodiversity, landscape, Indigenous culture and for contribution of savannas towards climatic and ecosystem stability.

Each land use (sector) i.e. grazing, mining, conservation and Indigenous use has direct and indirect benefits for itself and for other sectors. There are cross-border interactions across various land uses at a landscape level e.g. conservation on a grazing land would contribute to reduce soil erosion and thus, could add to the productivity on a grazing land. Some of the major land uses of savannas and their direct, indirect and non-use benefits are shown in Fig. 1.

The co-existence of multiple uses on one landscape enhances overall value. For example controlled grazing on an uncleared paddock could help to conserve wildlife. Tourism for various sectors (grazing, conservation and for aboriginal sites) could deliver educational and cultural benefits that can enhance tolerance among people. Similarly, preservation of Indigenous land could help to conserve floral and faunal diversity in additional to cultural values. Such synergies among various uses would offer opportunities to maximise benefits from tropical savannas and to diversify from existing land use. For this, it is important to identify:

- Multidimensional perspective of each land use
- Externalities (positive and negative)

Valuing multiple use of a natural system such as savannas is complicated. Generally, the addition of various benefits (or uses) of a natural system is used to

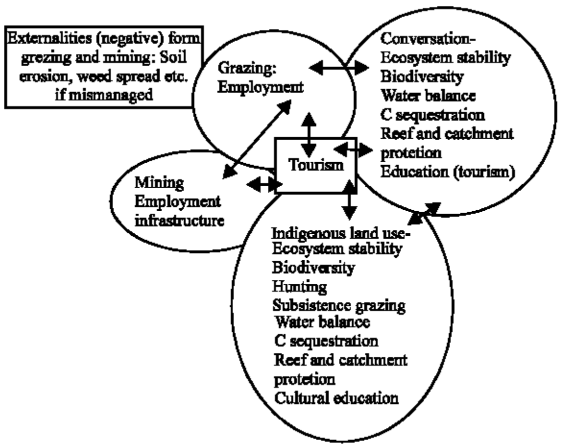

Fig. 1: Benefits, with cross-border interactions (indicated by arrows), from grazing, conservation, mining and indigenous land use in tropical savannas

estimate the Total Economic Value. Just an aggregate of ecosystem services does not always provide the total value of a system until interdependency and interactions among various components of landscape functions are taken into consideration. An account of interdependency of various ecosystem services of a natural system is very important to estimate Total Economic Value[4]. The Total Economic Value as an aggregate of main-function based values provided by an ecosystem even may not be equivalent to total system value, as the continued functioning of a healthy ecosystem is more than sum of its individual uses. There are also social, cultural or historical values associated with some natural systems, in particular for Australian tropical savannas. Many cultural, sacred, art and historic Indigenous sites are famous for tourists and play an important role in dissipating knowledge about Aboriginal culture to other sectors of the society. Thus it becomes of paramount importance to consider all the social, economic and ecological complexities among various uses while evaluating multiple uses of savannas. However, all over the world, studies are rare that target to value multiple uses of natural systems[4]. At the present, most of the benefits from various land uses i.e. grazing, mining or conservation are accounted separately, without considering the benefits of one land use to another. An important task for the present study is to assess the value of one land use to another which can further help build the synergies at a landscape level and to develop a model of multiple land use. For this, it is important to identify and estimate the value of cross-border interactions and of co-existence or integration of these usages at a landscape scale, which is envisaged to benefit the people in a much better way compared to the individual usage. This study presents a model of multiple land use and the methods to assess the Total Economic Value of various uses in savannas. Similar model of multiple land use could be applicable to other landscapes.

MATERIALS AND METHODS

Integration of various uses of savannas landscape needs an understanding of social, ecological and economic issues of the region and of positive and negative interactions between various uses and their effect on sustainability of natural resources. Australian savanna landscape is unique to study co-existence of various uses on a landscape scale, their synergistic and external effects.

This section describes the approach to estimate the value of various land uses of tropical savannas, including the costs/benefits associated with externalities. There are 2 steps:

Step 1: Identification of various land uses and the benefits from each land use including the positive and negative externalities.

The potential benefits and costs associated with various land uses in Australian savannas are listed in Table 1.

Step 2: Developing an economic framework to calculate the total benefits from savannas

To assess the total value of various uses in savannas for direct, indirect and non-use benefits, including externalities associated with each land use, a total economic valuation approach is preferred. All the listed benefits and costs for various land uses in Table 1 have some values. A framework on economic assessment of various costs and benefits for use and non-use values is presented as follows:

Total benefits from savannas = Net benefits from grazing, mining, conservation and Indigenous land use

Total benefits= $NB_G + NB_M + NB_{CON} + NB_{IND}$

NB_G : Net benefits from grazing

NB_M : Net benefits from mining

NB_{CON} : Net benefits from conservation

NB_{IND} : Net benefits from Indigenous land use

NB_G : Net Benefits from grazing

Grazing for beef production contributes largely to the Australian economy. There are direct monetary benefits and some negative externalities associated with grazing. Net benefits from grazing could be estimated separately for cleared or developed and for uncleared land or

Table 1: An overview of potential direct and indirect benefits (+) and costs (-) associated with land uses ('0' means not applicable)

Uses	Grazing	Mining	Conservation	Indigenous land use
Use values:				
Beef production	+++	0	0	0/+
Ore production	0	+++	0	0
Recreation/Tourism	0/+	-/+	+++	0/+
Indigenous culture	0	--	+/++	++
Non-use values:				
Ecosystem stability	-/0/+	0	++	++
Biodiversity protection	-/0/+	0	++	++
C sequestration	-/0/+	0	++	++
Hydrological balance	-/0/+	0	++	++
Soil fertility	-/0/+	0	++	++
Reef and catchment protection	-/0/+	0	++	++
Externalities:				
Soil erosion	-/0	--	0	0
CO_2 emissions	-/0	-/0	0	0
CH_4 emissions	-	0	0	-/0
Weed spread	-/0	-/0	-/0	-/0

woodland as the pasture production differs at these two land types[5]. The cleared land is sometimes sown to exotic grasses, while woodlands mainly support native grasses. Similarly, woodland pastures could be divided into types of woodland communities to account for their variable production potential.

$NB_G = \Sigma_k NB_{G,k}$

Where

k = 1, 2, (1 = cleared and 2= uncleared land)

NB_G = Use value ($a_k y_k p_k - a_k c_k$)+ Non-Use value ($a_k pb_k$)

where

a_k = area of land type k

y_k = cattle production from per area of land type k (number)

p_k = price of cattle/head

c_k = economic cost associated with cattle production on land type k

pb_k = public benefits or costs associated with land type k (such as soil erosion, CH_4 and CO_2 emissions)

NB_M: Net benefits from mining

NB_M = Use value ($a_i p - a_i c_i$)+ Non-Use value ($a_i pb_i$)

a_i _area of mining a particular ore i

c_i –cost of extraction

p. price for ore i

pb_i public benefits or costs e.g. benefits from mining to tourism/grazing for providing infrastructure or costs associated with mining for soil erosion and loss of biodiversity

Value of an ore from a mining area could be estimated directly from the market prices.

NB_{CON}: Net benefits from conservation

$NB_{CON} = [\{(a_i(BC_{seq}+B_{bio}+B_{ss}+B_{wb}+B_{rp}+B_{cp})\}-(pb_i)]$

a_i – conserved area at land type i

BC_{seq}-benefits from the amount of C sequestered by woody vegetation at area a_i

B_{bio}-benefits from conserving biodiversity at area a_i

B_{ss}-benefits for soil stability from conserving area a_i

B_{wb}-benefits for maintaining water balance at conserved area a_i

B_{rp} -benefits for the reef for conserving area a_i

B_{cp} -benefits for the catchment for conserving area a_i

pbi -Public costs for loss of beef production, or benefits of conservation of for Indigenous land use (hunting, art)

To calculate benefits from conservation, an opportunity cost method can be used[6].

For tropical savannas, the benefits for conserving an area will be estimated from the forgone benefits from livestock production.

NB_{CON} = Foregone benefits from grazing the similar cleared area (i.e. conservation in the same land zone as grazing).

NB_{IND}: Net benefits from Indigenous land use

$NB_{IND} = [\{(a_i(BC_{seq}+B_{bio}+B_{ss}+B_{wb}+B_{rp}+B_{cp})\}-(pb_i)]+ B_{CB}$

pb_i _Public costs for loss of beef production

B_{CB}– Cultural benefits and output benefits from Indigenous land use

The similar methods as those for conservation can be used to calculate the net benefits[6]. A component of cultural value is proposed to be included based on values from questionnaire surveys. The output benefits will be estimated from their direct cost and benefits.

NB_{IND} = Foregone benefits from grazing the similar cleared area (i.e. conserving same land zone as for grazing) + B_{CB} (cultural values e.g. from questionnaire surveys) + Value of output benefits

Value assessment for externalities

Negative externality: Example-Soil erosion from grazing and mining: Soil erosion from mismanagement of land under grazing or from mining affects the beef production. The onsite effect of soil erosion at a property would be evident in beef production and hence estimable through monetary gains. The following approach used for offsite impact of soil erosion[7,8] is applicable for savannas where the cost of soil erosion for non-forest areas was compared to forest:

Amount of soil saved from erosion by forests:
St = Sr – Sf
Sr = soil erosion in non-forest area
Sf = soil erosion in forest area
St = Sr-Sf = MrAr- MfAf
Mr- amount of soil eroded under non-forest area
Ar- area without forest
Mf- amount of soil eroded under forest area
Af- area under forest

Total amount of soil eroded in a particular vegetation-soil-slope type
MS(pi) = = ei ni k Ms (pi)
ei = vegetation type, ni = soil types and k = slope
Ms(pi)- soil erosion in vegetation-soil-slope complex

Value of soil erosion = Fe Co
Fe= effect derived from ecosystem service for saving from soil erosion
Co-opportunity cost

In this[7], the value of soil erosion in non-forest areas was estimated from the area of top layer of 0.5 cm thickness that eroded soil could make and then related to the direct benefits obtained from the same area of forests.

A similar approach could be used to estimate the cost for the amount of soil eroded in cleared compared to woodland pastures or conservation areas and then to calculate the potential beef production from the lost soil. The value of beef produced from lost soil would reflect the cost of soil erosion.

Positive externality: example-contribution of conserved land to improve pasture/cattle production at grazing land: The conserved area would contribute to improve soil hydrology and soil stability onsite as well as offsite. The value of such a positive externality could be estimated for the benefits of conservation area to improve the land productivity[9] as described below:
Externality = $(k1\text{-}k)B_k$
k1 - area under trees and crops (agroforestry)
k - area under forest
B_k- benefits obtained from annual crop (the details are mentioned in the study[9]).

RESULTS AND DISCUSSION

How to find the most efficient combination of various uses on a landscape for sustainable production gains: Allocation of resources for a particular land use is determined mainly from the economic efficiency. However there is a need to consider diversity (i.e. multiple use of land resources) and sustainability of resources. It is also important to set some criteria for maintaining a balance between economic efficiency and sustainability of natural resources to determine the tradeoffs between different land uses e.g. mining could be economically more efficient but exploits the natural resources over a long run.

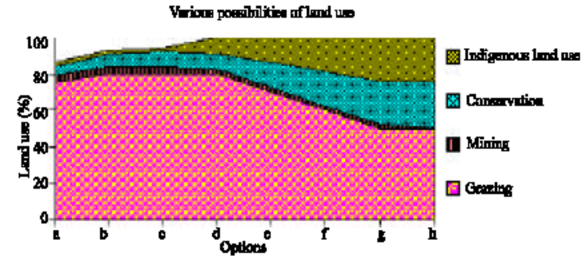

Fig. 2: Various hypothetical options of land use for efficient allocation of resources

After identifying land use options, their benefits, including the costs/benefits from externalities or cross-border effects of each land use, a model is developed for savannas (Fig. 2). The existing state of land use in tropical savannas could be a, b, or c (hypothetical options shown in Fig. 2). The use of natural resources can be maximized by testing the alternative options for example e, f, g or h (or more of these), where maximum returns from savanna landscape could be achieved without compromising the loss of benefits or services from an alternative land use. However, there would be some transactional costs or compensation associated with them. A detailed analysis on integration of various land uses of savannas is proposed to be conducted using some models (e.g. MGLP (Multiple Goal Linear Programming[10,11] and FASOM (Forest and Agricultural Sector Optimization Model[12])) or MCA (Multiple Criteria Analysis).

The present study aims to achieve the goals for multiple use of savannas through spatial differentiation rather than different uses on the same piece of land. The spatial differentiation of landscape to optimize benefits has been preferred for efficient returns in previous studies[13,14]. The efficient combination of various land uses (in Fig. 2) is imagined to be more sustainable than any one major land use.

The ‘multiple use’ of tropical savannas, in fact, is quite appropriate from ecological point of view. All the uses of an ecosystem are, indeed, important to sustain its healthy functioning. The capacity of soil to support diverse vegetation benefits the ecosystem in terms of resource allocation (if a particular grass requires x nutrient more, another grass type may need y nutrient more than any other nutrient). Thus a balance of available resources is maintained. The healthy functioning of various ecosystem processes supports the multiple uses and results in improved productivity. Thus, the multiple uses of savannas, in ecological terms, reflect functioning status of various ecological processes which are interlinked with each other and of their services.

This study deals only with natural resources in terms of land use to improve their allocation and presents an outline of economic framework to find the sustainable land use options with efficient returns. This study is a part of the large scale study project 'Multiple Use Opportunities for Northern Australia's Outback' which includes various legal (institutional property rights) and social issues linked with multiple use of land resources. The legal issues on property rights to use land resources for a particular use are discussed elsewhere[15,16], such as whether the lease hold land under grazing could be used for any uses other than grazing or not and what could be the legal reforms to implement such a change for diversification. Another important issue for multiple use of land resources is whether people of a particular region are willing to diversity or not[17] and about how their attitude could be changed[18] so that the poor resources in savannas could be managed for future generations.

This study presents a framework for multiple land uses in tropical savannas and for their value assessment and highlights the importance of synergies among different land uses to optimize resource utilization. Similar framework could be applicable to other landscapes where more than one land uses are possible to enhance the sustainable use of natural resources.

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