ELD CAMPUS

Self-study module on cost-benefit analysis of sustainable land management projects

Cost-benefit analysis of restoration of crop and rangelands in Eldamia

www.eld-initiative.org

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This document was published with the support of the European Union and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

The views expressed herein can in no way be taken to reflect the official opinion of the European Union or the German Federal Ministry for Economic Cooperation and Development (BMZ).

Photography:
GIZ (front and back cover, pg. 12, 44, 46, 50, 61); Silke Schwedes (pg. 15, 48); Vojtech Jurczak (pg. 18); Klaus Ackermann (pg. 22); Markus Kirchgessner/GIZ (pg. 69)

Visual concept: MediaCompany, Bonn Office

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Suggested citation:

ELD Initiative (2019). ELD Campus:
Self-study module on cost-benefit analysis of sustainable land management projects

Available from www.eld-initiative.org

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Acronyms and abbreviations

AGC	above ground carbon
ArcSWAT	a GIS-based interface for the Soil and Water Assessment Tool
A. specialis	Acacia specialis (fictional leguminous tree endogenous to Eldamia)
BCR	benefit cost ratio
CBA	cost-benefit analysis
CE	choice experiment
CIF	cost insurance freight
CO_2	carbon dioxide
EFS	Eldamia Forest Service
ELD	Economics of Land Degradation initiative
ES	Eldamia Shilling
FOB	free on-board
GDP	Gross domestic product
GIS	geographic information system
ha	hectare
IRR	internal rate of return
kg	kilogramme
km	kilometre
m	metre
MA	Millennium Ecosystem Assessment
mm	millimetre
MoA	Ministry of Agriculture
NPC	nominal protection coefficient
NPK	nitrogen, phosphorus, potassium
NPV	net present value
SCC	social cost of carbon
SLM	sustainable land management
SOC	soil organic carbon
TEV	total economic value
USD	United States dollar
US EPA	United States Environmental Protection Agency
WS1 etc.	worksheet 1 etc. in Excel files for Southern and Northern State case studies
WTP	willingness to pay

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01

Introduction to the self-study material

1.1 Context and objectives

Thematic background

Land degradation may constrain the provision of ecosystem services and social and economic development by reducing water, food and energy security and by triggering resource conflicts. The loss of natural capital presented by the world's land-based ecosystems threatens human wellbeing and sustainable development potential. Economic valuation of ecosystem services and incorporation into project appraisals based on cost-benefit analysis can advance mainstreaming of the value of nature and particularly ecosystems into business and public decision-making.

Economic valuation of ecosystem services can help decision makers by estimating the economic value of the ecosystem services to society, and by identifying how action can avoid the costs of losing services and/or gain the economic benefits of ecosystem rehabilitation. However, capacity building is needed and instructional materials such as this module will support this.

Target audience

These training materials are part of the ELD knowledge hub and ELD Campus (www.eld-initiative.org). They are aimed at **researchers in the field of land management**, and others, including teachers and students, who seek a better understanding of use of cost-benefit analysis for evaluation of environmental change and support to decision-making for sustainable land management (SLM) investments. The training materials are also directed at **professionals working on land management** who want to use the ELD approach and/or integrate the case study into their curriculum at their training centre or university.

Learning objectives

- To illustrate and explain key concepts and techniques for financial (private) and economic (social) appraisal of sustainable land management projects using cost-benefit analysis.
- To illustrate applications of economic valuation of ecosystem services in the context of decision-making for investment in sustainable land management.

Learning outcomes

- After completion of this module, you should be able to:
- selectively apply and critically evaluate the use of key concepts and methods in cost-benefit analysis including discounted cash flow analysis, measures of project worth and valuation estimates for environmental goods and ecosystem services;
- identify and compare land management costs and benefits over time for 'with' and 'without' project scenarios;
- calculate and interpret investment criteria including net present value and internal rate of return.

It is recommended to first study all the other modules in the ELD Campus to have a sound understanding on land degradation and sustainable land management, on the 6+1 ELD steps, on ecosystem services identification, selection and valuation as well as cost-benefit analysis!

1.2 General instructions for the use

Technical approach

These self-study materials employ the ELD initiative '6+1 step-wise approach' as a methodological framework. The 6+1 approach is a flexible framework that allows for adaptation to different contexts and situations. Current ELD materials, guides and case study reports have been used to inform the design and development of these learning materials.

The example case studies are fictitious but realistic, based on empirical description and data drawn from ELD country studies. For ease of presentation and interpretation some simplifications have been made and rounded values are used where possible.

The case studies provide examples that develop understanding of, and critical analytical skills for, the logical sequence of the 6+1 steps. They take the form of step-by-step cost-benefit analyses that compare the benefits of action towards SLM against the costs of inaction, and thus offer the ability to calculate benefits predicted to be derived from SLM.

Hints for the use

Two example cost-benefit analysis are provided (Eldamia Southern State and Northern State); in case of usage in on-site trainings or at university, these two cases could potentially be worked through by different groups of students/trainees although they include different learning elements. **Each case study with all exercises will require at least one working day!**

The materials are intended to be self-explanatory and self-contained. Some key technical concepts are defined and explained in inset boxes. Language, technical jargon and numerical examples have been kept as simple and accessible as possible. Spreadsheet-based exercises and worked examples are provided for the main steps of the cost-benefit analyses.

The symbols

Tasks and exercises are accompanied by these symbols:

the glasses for reading,

the notebook for tasks and exercises.

Solutions are provided at the end of the respective chapters!

The conventions and terminology for cost-benefit analysis that are used follow those generally applied by the World Bank and other leading multi-lateral financial institutions. Key references for this are Belli et al., 2001 and Gittinger, 1982[1].

This self-study module is accompanied by the following files in Excel:

- Eldamia Southern State workbook.xlsx
- Eldamia Southern State workbook solution.xlsx
- Eldamia Northern State workbook.xlsx
- Eldamia Northern State workbook solution.xlsx

Before you start, make a backup copy of the two workbook files, so that you can return to them after working on exercises by using the original copy, if necessary!

Activity: Read section 1 to commence your study of this module!

[1] *Belli, P., Anderson, J.R., Barnum, H.N., Dixon, J.A. & Tan, J. (2001) Economic Analysis of Investment Operations: Analytical Tools and Practical Applications. Washington DC, The World Bank.*

Gittinger, J.P. (1982) Economic Analysis of Agricultural Projects, (2nd edition), Baltimore, Johns Hopkins University Press.

1.3 The case study scenarios – Case study introduction: 'Welcome to Eldamia'

Sub-section learning outcome:
- An initial appreciation of the fictional case study scenarios

Case study introduction: 'Welcome to Eldamia'
Eldamia, officially the Republic of Eldamia, is a semi-arid country with a total land area of approximately 44000 km^2 (a size similar to Dominican Republic or Slovakia), and a population of approximately 11 million (similar to Dominican Republic or Burundi). Approximately, 55% of the population live in cities and 45% in rural areas. Almost a third of people are classified as poor.

Eldamia is a developing country with a market-oriented economy. The GDP per capita was approximately USD 3000 in 2019 (similar, for example, to Egypt, Ukraine and Venezuela).

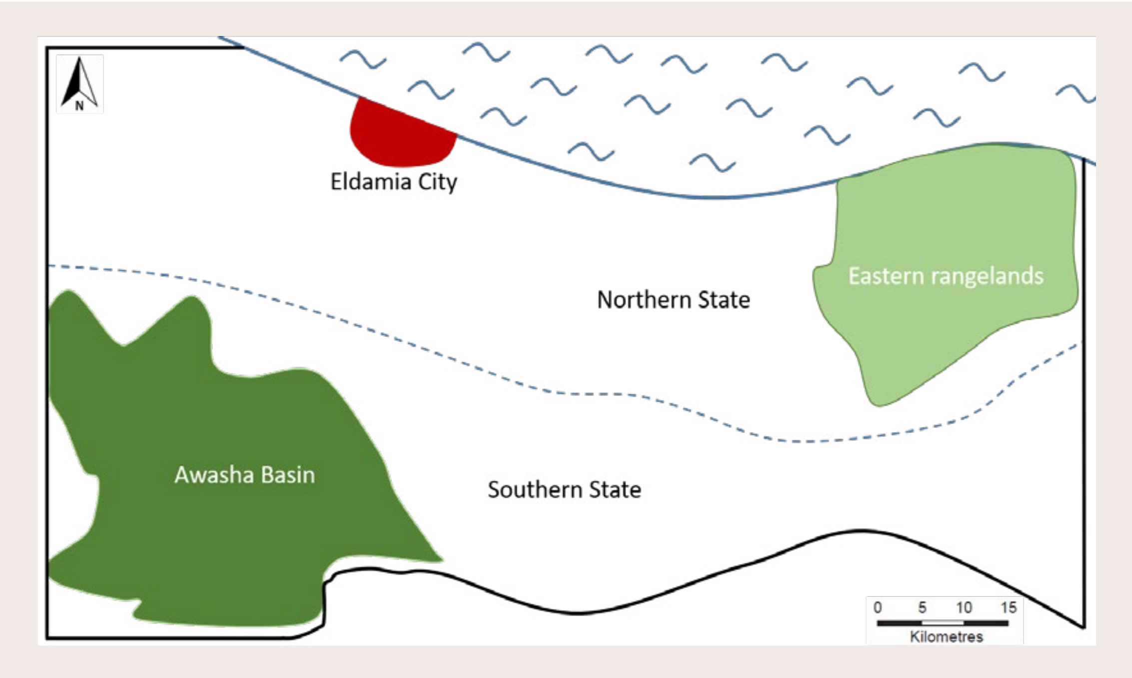
The agricultural sector still generates approximately 50% of the national GDP, and subsistence and commercial agriculture supplemented by small-scale fishing and the collection of forest and desert products underpins the livelihoods of the rural population. The main agricultural products are sorghum, sesame, maize and livestock, and the main agricultural export commodities are meat and hides, and to a lesser degree timber and tree gum. Tourism is gaining importance from a very low base as the country's beaches, coral reefs, mountains and deserts are attractions.

The currency is the Eldamia Shilling (ES). Currently, the exchange rate is USD 1 = ES 10.

Eldamia has a northern coastline approximately 95 km in length and consists of two provinces: Northern State and Southern State (Figure 1). The country also divides into two main geographic and climatic areas that correspond approximately to the boundaries of the two provinces.

FIGURE 1

Map of Eldamia
Source: Smith, 2019



Southern State

The Southern State, and especially its western region, was previously known as the food basket of Eldamia and is an area of extensive rainfed agriculture. Over several decades unsustainable agricultural practices that combined near-monocropping with low nutrient replenishment have led to significant degradation of soils which are often no longer able to sustain farmer livelihoods and regional, let alone national, food security.

The most widespread physical feature of the region is a clay plain, gently sloping to the south, its monotony broken by groups of low hills to the south and east. This clay plain is dark brown, almost black in colour and deeply cracked and bone-hard in summer but swells to become muddy and often impassable in the rains. In the north it is covered with short annual grasses which dry to a silvery grey, and scattered thorn bushes which concentrate to form dense thickets along the meandering lines of seasonal watercourses. In the south there are tall, coarse perennial grasses and some remains of very open forests of deciduous tree species.

Annual rainfall ranges from 450-700mm, increasing from north to south. Rainfall is essentially seasonal, most falling in June, July, August and early September, although showers in late April or May are not uncommon. Few hills in the region rise more than 225 metres above the plain and topography has little influence on the distribution of local rainfall. Mean temperatures are highest in April and May when the sun is overhead and lowest in August at the height of the rains, when sun temperatures are reduced by cloud cover and evaporation of rainfall.

Northern State

Away from the coastal strip, the Northern State is primarily a region of desert and desert steppe, with elevations varying from 600-900m above sea level and annual mean rainfall ranging from 100-200 mm. Here land use is primarily as rangelands. Sustainable land management is generally lacking, and worsening desertification, land degradation and droughts since the year 2000 are threatening the ecosystem services, including livestock production, that this region offers to its human population and natural biodiversity.

Eldamia and proposed SLM projects – key facts and figures

Total land area	44000 km^2
Population	11 million
GDP per capita (2019)	USD 3000
Exchange rate for Eldamian Shilling	USD 1 = ES 10
Administrative divisions (provinces)	Southern State and Northern State
Rural:Urban population, percentage	45:55 %

Proposed projects

A) Sustainable Land Management in Southern State	
Annual rainfall	450–700 mm
Potential project area (project scale to be confirmed)	569219 hectares
Potential for agroforestry	537675 hectares
Potential for reforestation of barren hills	28676 hectares
Potential for cultivated slopes to be terraced	2868 hectares

B) Rangeland restoration in Northern State	
Annual rainfall	100–200 mm
Area of eastern rangelands	380000 hectares
Area suitable for rangeland restoration	109000 hectares
Proposed pilot project	4000 hectares
Consisting of 10 rangeland management units of:	400 hectares

1.4 'Road map' for the case study and its steps

Sub-section learning outcome:
- Understanding of the sequence and structure of the case study and how to work through it

First, complete your reading of Section 1.

Then work through the Southern State case study (Sections 2 to 7)!

Then work through the Northern State case study (Sections 8 to 13)!

For the fictional case study of Eldamia the following scenarios are to be analysed.

In Southern State:
- a 'without project' or 'baseline' scenario consisting of 'business as usual' and no continuing change or trend in the current state of land degradation;

compared to

- a 'with project' sustainable land management (SLM) scenario consisting of investments made and interventions carried out to reduce land degradation and improve ecosystem service provision.

In Northern State:
- a 'without project' or 'baseline' scenario consisting of 'business-as-usual' and a continuing trend of worsening land degradation;

compared to

- a 'with project' SLM scenario consisting of investments made and interventions carried out to reduce land degradation and improve ecosystem service provision.

ROAD MAP FOR THE CASE STUDIES

Part A) Southern State case study

Activity 1: Read Section 2

↓

Activity 2: Read Section 3 and study Worksheet 1 (WS1) in the Excel workbook file for Southern State

↓

Exercise 1: Identify ecosystem services in the Awasha Basin

↓

Exercise 2: Make entries for sesame yield for the SLM scenario in WS1

↓

Exercise 3: Make entry for variable farm production costs for SLM scenario in WS1

↓

Activity 3: Read Section 4 and study WS2 in the Excel workbook for Southern State

↓

Activity 4: Read Section 5

↓

Activity 5: Read Section 6

↓

Exercise 4: Completing benefit and cost streams

↓

Exercise 5: Calculating measures of project worth

↓

Exercise 6: Sensitivity analysis for the SLM scenario

↓

Activity 6: Read Section 7

↓

Completes Part A)

Part B) Northern State case study

Activity 7: Read Section 8

↓

Activity 8: Read Section 9 and study WS1 in the Excel workbook for Northern State

↓

Exercise 7: Identify ecosystem services from the eastern rangelands

↓

Exercise 8: Make entry for shallow aquifer recharge in SLM scenario in WS1

↓

Exercise 9: Enter data for rates of carbon sequestration in WS1

↓

Activity 9: Read Section 10 and study WS2 in the Excel workbook for Northern State

↓

Activity 10: Read Section 11

↓

Activity 11: Read Section 12

↓

Exercise 10: Building benefit and cost streams at community level

↓

Exercise 11: Calculating measures of project worth for rangeland restoration

↓

Exercise 12: Sensitivity analysis for rangeland restoration

↓

Activity 12: Read Section 13

↓

Completes Part B)

SUMMARY OF THE ELD 6+1 STEPWISE APPROACH[2]

1. Inception	Based on stakeholder consultation, identification of the scope, location, potential spatial scale, and strategic focus of the study. Collation of background data on the socio-economic and environmental context of the assessment.
2. Geographical characteristics	Establishment of geographic and ecological boundaries of the study area, following an assessment of quantity, spatial distribution, and ecological characteristics of land cover categories analysed using GIS.
3. Types of ecosystem services	For each land cover category: identification and analysis of stocks and flows of ecosystem services; classified as: provisioning, regulating, cultural, and supporting services.
4. Roles of ecosystem services and economic valuation	Establishment of the livelihood roles of ecosystem services in each land cover area for communities and economic development. Estimation of the total economic value for each ecosystem service.
5. Patterns and pressures	Identification of land degradation patterns and drivers, pressures on sustainable management of land resources and drivers of adoption of sustainable land management. Revision of previous steps if needed, to ensure the assessment is as comprehensive as possible
6. Cost-benefit analysis and decision making	Cost-benefit analysis (CBA) comparing costs and benefits of an 'action' scenario to that of a 'business-as-usual' scenario to assess whether the proposed land management changes lead to net benefits. Identification of 'on-the-ground' and policy actions that are economically desirable.
7. Take action	Land users: to implement economically viable changes in land management practices or land use. Private sector: to implement actions that enhance investment in sustainable land management and supporting supply chains and scaling up of those actions. Policy-/decision-makers: to facilitate adoption and sustainability of economically viable actions by adapting the legal, policy, institutional and economic contexts at relevant scales and levels.

2 For more information and detail see: ELD Initiative (2015). ELD Initiative User Guide: A 6+1 step approach to assess the economics of land management. GIZ: Bonn, Germany.

Available from www.eld-initiative.org

Part A

Southern State case study

02 ELD steps 1 and 2 Inception and geographical characteristics

Activity 1: Read Section 2

Section learning outcomes

- This section illustrates information in a brief form that would be compiled and assessed in more depth for ELD steps 1 and 2 for a real application. Reflect on the importance of ensuring that the cultural, biophysical, and socioeconomic (including institutional) situation, needs and drivers are understood before proceeding with SLM scenario development! Also, on the importance of identifying the scale, geographical boundaries and land cover categories for the study (information typically gathered within a GIS-based approach and participatory GIS framework)!

2.1 Inception: context and aims for the cost-benefit analysis (CBA)

In the farming areas of Southern State clay soils are predominant. These soils have poor organic matter and nitrogen content, and form cracks from the surface downward when they dry out. They become very dry in the dry season, but slow infiltration and percolation can lead to very heavy soils and localised waterlogging in the wet season. Tillage is therefore difficult except for a short period between the dry and the wet season, and this has encouraged mechanisation of this operation.

FIGURE 2

Loss of soil fertility in Eldamia

The main crops are sorghum and to a lesser extent sesame and maize, all grown during the wet season from June to September. In previously productive areas, the near-monocropping farming system has led to the destruction of vegetative cover and the degradation of soil fertility.

Alongside degraded agricultural soils on the plain, the landscape features denuded hills with shallow soils and occasional remaining trees. Such hilly areas are either communally or state owned, but some of their slopes near settlements, and particularly in the better-watered south, have become permanently cultivated by individuals. These farms are usually small, mainly used for subsistence, and often cultivated primarily by women.

Agricultural practices such as extensive adoption of mechanised rainfed agriculture, clear-cutting of vegetative woody biomass for fuelwood and land clearance, shortening of fallow periods and cultivation on steep slopes have all contributed to land degradation. The farming system is neither fully mechanised nor traditional. Primary tillage is mechanised apart from on hillsides, but sorghum, sesame and maize production is still extensive and involves hand weeding and harvesting. Replenishment of soil nutrients by organic matter is inadequate and traditional local cultivars are cultivated with little use of fertilisers to supplement the soil. All these factors continue to degrade the soil leading to a decline in land productivity. This impacts food security in the region, increasing the vulnerabilities of the rural poor to climatic and weather uncertainties.

Unsustainable land management practices in the region have been attributed to the lack of local participation in decisions affecting land management and the lack of appropriate land tenure regimes; both acting as disincentives to land users to invest in more sustainable practices. Many farmers depend on leaseholds or informal tenure arrangements and lack land tenure security. Indiscriminate clear-cutting of forests for mechanised farming, coupled with disincentives to grow trees on farmland, has also led to dependence by the rural population on natural forest reserves for domestic energy and timber for construction. In response to this, and to relieve pressure on forest reserves, the national Forest Service (EFS) requires 10% of total farmland in Southern State to be planted with trees. This policy has yet to be fully enforced and adoption by farmers is slow; not least as the upfront costs and labour demands of planting trees tends to prohibit smallholders from taking up this practice.

Sustainable land use practices and recovery of soil fertility are key to reversing the current land degradation trends. One solution, possible at a large scale, is to promote the planting, utilisation, and regeneration of native leguminous trees. Additionally, a solution for hillsides that are cultivated is construction of physical terraces to retain soil and moisture. This will help sustain soil fertility and increase crop yields on cultivated slopes.

A sustainable land management strategy employing three components is proposed:

1. **agroforestry on cropped flat lands** where primary cultivation is mechanised, and farms are quite large and commercially oriented (the agroforestry will consist of intercropping of sorghum and sesame between Acacia specialis, a native leguminous tree);

2. **the reforestation of degraded hilly areas** that are currently unused through planting of A. specialis and other related species;

3. **construction of physical terraces on slopes** near settlements that are used for cultivation of maize and sometimes vegetables.

A. specialis is a leguminous tree species that can contribute to the sustainability of open parkland, agroforestry and alley cropping systems in semi-arid regions. Its gum is of high quality and can be tapped outside the main harvesting season for cereals. It is a substitute for other similar products (including gum arabic), it is already internationally traded and hence it is an exportable commodity. Before the advent of mechanised farming across large areas, similar trees were integrated into a local system of shifting cultivation or bush-fallow cycle. Trees were used for gum production for 15 to 20 years, interspersed with a short period of cultivation (4 to 6 years). This system is now very rarely practiced in Eldamia as farmers are cash and land constrained and grow crops annually for subsistence.

The integration of A. specialis trees with staple crops may help to diversify income sources, while also sustaining food security and improving soil fertility. This strategy is thought to have potential for adoption amongst both small-scale subsistence farmers and larger farmers in Southern State, as it requires few capital inputs and low maintenance. This was confirmed from focus groups with farmers and experts in the study area. Other literature also provides evidence of willingness amongst local people in Southern State to integrate trees in their farming systems as they may also provide fuelwood and timber for construction.

The second part of the SLM strategy is the reforestation of barren hills with A. specialis and other species. Incentives for such restoration in communal areas must be assessed, but prior studies suggest that an effective forestry extension service can encourage farmers to plant trees on common land. This can especially be promoted amongst land constrained smallholders for whom the opportunity cost of tree planting on their own land is high. During field visits, A. specialis and other related species have been identified by a farmer group and biophysical experts as effective for restoration due to their drought tolerance and the value of their gum and timber production. Additionally, the improvement or establishment of protective forests on ridge tops, hillsides and near water bodies may help trap sediments, improve groundwater recharge and sequester carbon.

For the third part of the SLM strategy, it is proposed that farmers construct physical terraces to retain soil and moisture on sloping land used intensively to grow maize and some other crops. This should sustain and improve soil fertility and increase crop yields.

Thus, options for land restoration in suitable areas of Southern State have been identified and researched for their bio-physical and socio-cultural feasibility. An appraisal of the potential economic benefits of these is needed to inform policy and investment decisions and design choices for implementation.

2.2 Geographical characteristics

The study area is a shallow drainage basin bounded by low watersheds in the south west of the state (see figure 1) and dotted with low hills to its east and south where settlements and cultivation on slopes also tend to be concentrated. Known as the Awasha Basin, its total area is 716,900 ha (7169 km^2) and its geographical position lies between 12.6 to 14.4°N, and 33.6 to 36.4°E.

2.3 Section summary

In Southern State the study area is the Awasha Basin in south west Eldamia. An economic cost-benefit analysis is needed to compare current land degradation to a scenario in which investments are made and SLM improvements achieved.

The SLM scenario to be appraised using cost-benefit analysis consists of:

1. agroforestry with a leguminous tree intercropped with sorghum and sesame on flat lands;
2. reforestation of degraded and mostly barren hills;
3. construction of physical terraces on hillsides that are used for cultivation of maize and vegetables.

ELD step 3 Types of ecosystem services

Section learning outcomes

- Appreciation of how this step involves refining the analysis within agro-ecological zones and assessing the type and state of ecosystem services stocks and flows in the study area;
- Appreciation of use of the MA (2005) ecosystem categorisation by type, i.e.: provisioning, regulating, cultural, and supporting services.

3.1 Ecosystem services identified

Land degradation in Southern State has a significant impact on ecosystem function and provision of ecosystem services, reducing the availability and quality of water, soil and plant resources for society and economy.

Exercise 1:
Identify ecosystem services from the Awasha Basin

Before proceeding, review the description of the area given in sections 1 and 2 above. Then 'brainstorm' and write your own list of the ecosystem services which you think are produced in this area. Then categorise your list into provisioning, regulating, supporting and cultural services. You might want to refer to the module on the identification and selection of ecosystem services within the ELD Campus as well.

Answer guideline: When you have drafted and categorised your list compare it to table 1 below.

Do you think we have missed out anything important in table 1?

In practice, we should go back to the local stakeholders to discuss and confirm our findings before proceeding with the design and appraisal of our proposed project!

Activity 2: Read Section 3 and study Worksheet 1 (WS1) in the Excel workbook file for Southern State

Table 1 provides a categorised identification of ecosystem service provision in the study area. These services are discussed further below, and data sources for their quantification are outlined.

TABLE 1

Preliminary identification of ecosystem services in Southern State study area

Category	Ecosystem services
A) Provisioning	A1: increased crop production
	A2: tree gum production from A. specialis trees
	A3: firewood from old trees
B) Regulating	B1: nitrogen fixation
	B2: soil moisture conservation
	B3: sediment stabilisation and reduction in soil erosion
	B4: increased infiltration and reduced runoff
C) Supporting	C1: carbon sequestration
D) Cultural	D1: sustained farming systems and rural livelihoods

3.2 Detail and data sources for ecosystem services and project costs

As you read the details below, see how the data required for the cost-benefit analysis (CBA) has been entered and prepared in the Excel worksheet WS1. Note that three columns are colour shaded and show data for the pre-project situation, the baseline scenario (without project) and SLM scenario (with project).

Also read the box CBA Explanation: Identifying costs and benefits and refer to the module on CBA within the ELD Campus.

Key point! Note that in WS1 any raw data values are only entered once. The number of raw data entries is kept to the minimum and all other values are calculated using formulae and cell references. This builds a 'model' of the project that can later be used for sensitivity analysis as we shall see below.

Key tip! If you are not very familiar with using formulae in Excel, use the help function to look up an explanation of 'relative', 'absolute' and 'mixed' cell references. This will help you build up spreadsheet models more quickly by enabling you to copy formulae from one cell to another when a repeated or similar calculation is needed.

CBA explanation: Identifying costs and benefits

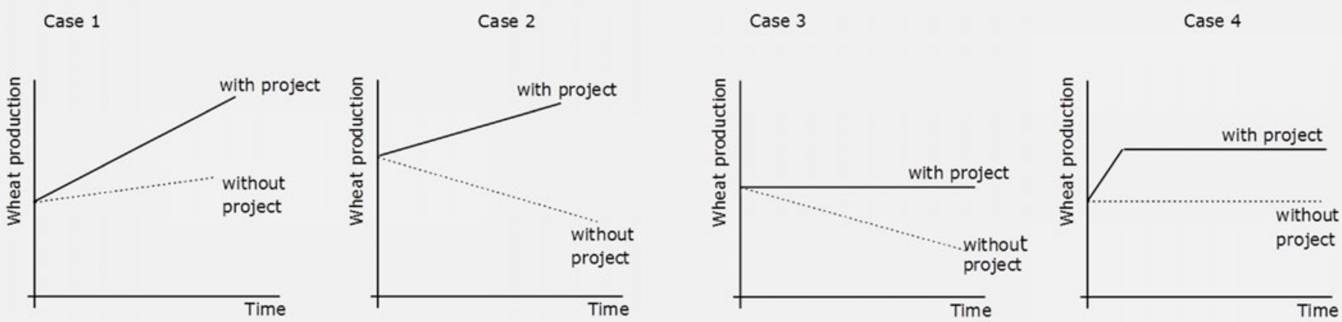
Costs are anything that reduces an objective and benefits are anything that contributes to an objective. In seeking the best projects and the best designs for those projects, the objective and decision criterion is maximum net benefit measured in terms of money, and hence costs and benefits are also valued in money where possible.

Most projects to improve SLM will involve agriculture and/or forestry. The preparation of a cost-benefit analysis starts from the identification of costs and benefits. Most often this will be carried out per unit area of land and at farm level, and then in aggregate for the whole project or study area. The same approach can be adopted for other rural activities, e.g. forestry lots or ponds for aquaculture. The principle is to build up from individual microenterprises to aggregated values for a group, community, sector or landscape unit.

A project analyst should normally apply two viewpoints: (i) that of individuals or businesses concerned with private profitability; and (ii) that of society concerned with allocative (i.e. economic) efficiency and thus net benefit for the economy.

Project analysis tries to identify and value projected costs and benefits that will arise 'with' the project over time and to compare them with the situation as it would be 'without' the project. The difference is the incremental net benefit arising from the project investment. This approach is not the same as comparing the situation 'before' and 'after' the project. Such a before and after comparison fails to account for changes that may occur over time without the project and leads to erroneous prediction of the benefits attributable to the project.

The figure below illustrates four possible scenarios. Only in case 4 is a 'before and after' comparison in each year or time period used equivalent to the 'with' versus 'without' project comparison.



Source: Smith 2019. This figure is adapted from Gittinger, J.P. (1982) Economic Analysis of Agricultural Projects, (2nd edition), Baltimore, Johns Hopkins University Press, pages 48-50

The ecosystem services to be gained or enhanced through the SLM strategy for Southern State include:

A) Provisioning services

To collect data for provisioning services a household survey was implemented. The survey collected data related to socio-demographic characteristics, crop production, farming practices, and prices of inputs and products. 200 households were interviewed in representative villages selected as advised by the EFS as locations where farmers showed interest in agroforestry.

Also, relevant biophysical data were collected for ground-truthing of a land use and cover map based on satellite imagery. Biophysical functions including water infiltration, soil moisture and sediment stabilisation were then modelled using the Soil and Water Assessment Tool (ArcSWAT). Model outputs for soil moisture, plus agronomic experimental data for the impact of A. specialis agroforestry on soil nitrogen level, were input to AquaCrop (an integrated crop-water balance model) to predict crop yields over 25 years.

For the agroforestry component of the SLM strategy on flatland farms, A. specialis is to be planted at 6x6 meter spacing with sorghum or sesame between the rows of trees. This spacing ensures machinery can pass unhindered and corresponds to 278 trees/ha. The amount of land lost to crops per hectare is equivalent to 12.5% of the area.

For the reforestation component, trees will be planted on barren hills. The area suitable for reforestation was calculated based on the rainfall gradient. A. specialis and other similar species are widely distributed and resilient to both drought and frost, growing in areas with an annual rainfall of 200 – 800 mm.

For the terracing component, 80% of the hillsides currently cultivated have been identified as suitable for terracing, and communities in these areas have expressed interest in this. Construction of terraces will reduce the cropped area of hillsides currently cultivated by 10% because of the area taken up by the terraces.

A1: increased crop production from improvements in soil fertility and soil moisture status

Agroforestry component: the main impacts of A. specialis trees on cereal yields are their ability to fix nitrogen and retrieve it from below the rooting zone of crops (which contributes to an increased nitrogen stock in the soil). The trees also create a microclimate which reduces soil drying and improve soil porosity to increase infiltration and reduce runoff. Under the SLM scenario, sorghum yields are predicted to decline by 20% for the first three years because of initial competition effects, but then increase as the trees enhance soil moisture and nitrogen content: by 15% from the fourth year and by 28% cent from the tenth year. Sesame yields are also predicted to decline by 20% for the first three years, but then increase by 10% from the fourth year and by 22% cent from the tenth year.

All crop residues are burnt or incorporated in the soil by mechanised tillage as demand for straw for livestock or other purposes in the region is very low.

Exercise 2:
Make entries for sesame yield for the SLM scenario in WS1

Using the data already entered in WS1 (Excel file), enter formulae to calculate the predicted sesame yield per hectare in years 4 to 9 (cell E28) and years 10 to 25 (cell E29 in WS1) (replace the question marks in those cells).

Answer guideline: see box at the end of this chapter 3 – after the section summary!

Terracing component: consideration of the beneficial ecosystem services enhanced by this component has been limited to improved maize yields in the absence of other relevant data (other vegetable crops grown are diverse and details could not be readily collected within the time and resource constraints of the household survey). See data in rows 84 to 86 in WS1.

A2: tree gum production

A valuable export, it can be used in confectionary, pharmaceuticals, printing, and pesticides. The production of tree gum can help enhance smallholder livelihoods and reduce inter-year variability of their income, since gum tapping takes place outside the grain harvesting season.

Prior agronomic studies indicate that gum collection can start in the fifth year after planting and continue until the twenty-fifth year. Peak production occurs between years 10 and 20 (See data in WS1).

A3: firewood from old trees that no longer produce significant or good quality gum

When the trees are 25 years old, they are cut and used for firewood. According to the EFS, the firewood from a 25 year old tree is estimated to be 0.07 m3, equivalent to about 20 m3/ha assuming 278 trees/ha.
(Firewood and fodder produced annually from pruning of trees is negligible).

(Note that the provisioning services of A. specialis and other trees planted on barren hills in the reforestation component of the SLM strategy are not considered or valued in this assessment. This is because the common land ownership situation leaves it unclear who will harvest these benefits and how consistently they will do so. Thus, the benefits of provisioning services from the reforestation component of the SLM strategy in Southern State may be underestimated in aggregate).

B) Regulating services

B1: nitrogen fixation

A. specialis fixes atmospheric nitrogen thus contributing to increasing crop yields and restoring soil fertility as considered above.

B2: soil moisture conservation

The microclimate created by the trees, including shade and windbreak effects, and improved soil porosity can conserve soil moisture and contribute to crop yields as considered above.

B3: sediment stabilisation and reduced soil erosion

The deep taproot and extensive lateral root system of A. specialis modifies soil porosity and infiltration rates thereby reducing runoff and trapping and stabilizing sediments. ArcSWAT predicted that annual soil erosion rates on the flatlands will halve as a result of implementing agroforestry compared to the pre-project situation. Equivalent nutrient losses of nitrogen and phosphorus were also calculated.

B4: increased infiltration and reduced runoff

This contributes to recharge of the shallow aquifer helping to reduce drying up of water points in the dry season. ArcSWAT analysis predicted that A. specialis agroforestry and reforestation of barren hills will improve infiltration and increase the availability of water at water points. Additional to the increased soil moisture that contributes to crop yields as considered above, ground water percolation that contributes to shallow aquifer recharge is predicted to increase by 30% on the cropped flatlands and by 35% on reforested hills in the SLM scenario compared to the pre-project situation and baseline scenario.

C) Supporting services

C1: carbon sequestration

Through the storage of above and below-ground carbon within the woody biomass. The additional carbon sequestered above and below ground as a result of the SLM scenario was estimated using IPCC tier 1 methodology (IPCC, 2003) with adjustments for local conditions and tree planting density. Changes in carbon and carbon dioxide equivalent stocks were estimated. Compared to the baseline scenario, 2 to 3 tons of incremental carbon per hectare per year are sequestered under the A. specialis agroforestry component depending on the age of the trees (see WS1).

The reforestation of hills is similarly projected to increase soil carbon stocks by 8 to 11 tonnes per hectare per year over the life of the trees.

D) Cultural services

D1: sustained farming systems and rural livelihoods

Considered intangible, and no attempt made for quantification and valuation in addition to that for the relevant provisioning services considered above.

Project costs (Southern State)

For the agroforestry component, to account for planting and management costs of the trees as well as change in production costs of the intercropped sorghum and sesame, data was derived from expert interviews to complement the household survey. The survey revealed that farming practices were very homogenous amongst farmers in the study area.

Intercropping with trees changes the production cost (land preparation, machinery hire, seed and sowing, weeding and harvesting) of the prevailing sorghum and sesame cropping pattern per unit area compared to the baseline scenario. The cost is lower with agroforestry because of reduced seed and weeding costs. No extra costs are associated with land preparation as machinery is still used. Modest tree pruning and maintenance costs commence in the second year and harvest of tree gum in the fifth year. Finally, in year 25 there are costs to cut the trees for firewood (see data in WS1).

Exercise 3:
Make entry for variable farm production costs for SLM scenario in WS1

Using the data already entered in WS1 (Excel file), enter a formula to calculate the predicted variable farm production costs for the agroforestry component (cell E48 in WS1).

Answer guideline: see box at the end of this chapter 3- after the section summary!

Significant project implementation costs include the provision of extension services to farmers to promote agroforestry and provide ongoing advice and support. Costs for an initial extension campaign to encourage adoption and annual costs for farm support and advice have been estimated for the whole area in the Awasha Basin potentially suitable for agroforestry. Cost values per hectare have then been used in the analysis, to enable pilot projects of different scales to be appraised (see WS1).

For the reforestation component, costs of planting trees on barren hills are only incurred in the first year since it is assumed that the trees are planted by a government agency (EFS) and no further costs are incurred.

For the terracing component, maize production cost per unit area is reduced compared to the baseline scenario because of the reduced input and labour costs associated with the loss of area taken up by the terraces. Farmers also incur labour costs for terrace construction and annual maintenance. (See WS1).

Project level costs for farm extension for promotion and adoption of terraces, and for annual advice are also incurred as estimated and shown in WS1.

3.3 Section summary

In this section ecosystem services for the Southern State study area have been identified and categorised. Data sources and quantitative descriptive data have also been summarised. The relevant data is shown in WS1 in the Excel file, where it has been entered as the first stage in building up a cost- benefit analysis.

It is important to understand how the necessary data has been predicted for the baseline (without project) and SLM (with project) scenarios, and how this is presented in the spreadsheet. This establishes the basis for comparing the incremental costs and benefits arising in the project and hence the determination of incremental net benefit.

It is important to understand which benefits and costs have been identified and quantified (if not yet all valued) for each project component. Also, to recognise and take note of benefits or costs which may not have been quantified so far because of a lack of data or for other reasons. Such omissions should be kept in mind when the results of the CBA are interpreted in Sections 6 and 7 below.

Solutions to the exercises in this chapter:

Exercise 2:
The calculated values shown in your worksheet should be
cell E28 – 660 kg/ha
cell E29 – 732 kg/ha

Exercise 3:
The calculated value shown in your worksheet should be
cell E48 – 900 ES/ha

ELD step 4 Role of ecosystem services and economic valuation

Section learning outcomes

- Appreciation of illustrations of the role of identified ecosystems services in the livelihoods of the communities and overall economic development of the study zone;
- Practice in working with estimates of the total economic value (TEV) of these services (use and non-use values);
- Appreciation of illustrations of how these estimates seek to apply the concept of TEV[3], combining non-use values (which are normally difficult to quantify) with use-values to provide a holistic societal valuation rather than a purely market-based financial one;
- Appreciation of possible biases, inaccuracies and uncertainty in the assessment of economic values.

4.1 Ecosystem services valued and valuation methods used

Table 2 summarises the benefits (ecosystem goods and services) valued and the valuation method that was used. These valuations are discussed further below, and data sources used are outlined. You can refer to the module on ecosystem valuation within the ELD Campus for more information on the valuation methods.

Activity 3: Read Section 4 and study WS2 in the Excel workbook for Southern State

TABLE 2

Ecosystem goods and services valued for Southern State study area and the valuation approach used

Category	Ecosystem services	Biophysical impact	Valuation approach
A) Provisioning	A1: increased crop production	incremental crop yield increase	market prices
	A2: tree gum production from A. *specialis* trees	gum produced	market prices
	A3: firewood from old trees	firewood produced	market prices
B) Regulating	B1: nitrogen fixation	increased crop yields	change in productivity approach and use of market prices
	B2: soil moisture conservation	increased crop yields	change in productivity approach and use of market prices
	B3: sediment stabilisation and reduction in soil erosion	impact on nitrogen and phosphorus	replacement cost for fertilisers in market prices
	B4: increased infiltration and reduced runoff	increased infiltration to shallow aquifer	replacement cost for purchase of water in market prices
C) Supporting	C1: carbon sequestration	CO_2 sequestered	avoided damage cost, using the social cost of carbon

3 *For more on TEV of environmental goods and services, and environmental valuation methods applied to land management options see module on ecosystem services valuation and ELD Initiative (2015). The value of land: Prosperous lands and positive rewards through sustainable land management. Available from www.eld-initiative.org*

4.2 Detail and data sources for economic valuation

As you read the details below, see how the data required for the cost-benefit analysis (CBA) has been entered and prepared in the Excel worksheet WS2 and how it relates to data in WS1. Note that three columns are again colour shaded and show data for the pre-project situation, the baseline scenario and SLM scenario.

Also read the following boxes as you progress through this sub-section:
CBA explanation:
valuation viewpoints, shadow prices and terminology
CBA explanation:
future prices for costs and benefits
CBA explanation:
environmental valuation – change in productivity approach
CBA explanation:
environmental valuation – replacement cost
CBA explanation:
environmental valuation – avoided damage expenditure
CBA explanation:
the relevance of economic valuation

You might want to refer to the modules on valuating ecosystem services and on CBA within the ELD Campus for further explanations on the valuation methods and economic terms.

CBA explanation: Valuation viewpoints, shadow prices and terminology

Valuation viewpoints:

The aim of economic cost-benefit analysis is to estimate the value of a proposed project to the nation or society. It thus requires a framework within which costs and benefits can be identified and assessed from society's perspective or viewpoint.

But it is also often necessary to assess the financial effects of a project for its participants. In SLM projects this usually means farm families and other land users. Financial appraisal at the farm level is particularly important in developing countries where farmers may be poor and vulnerable to risk. Incentives that are enough in amount and reliability are essential to encourage farmers to participate in a project that involves new inputs, outputs and/or technologies. Thus, projected farm budgets for representative farms are needed to assess cash flows and the viability of investments and any debt repayment. The expected incentives must sufficiently reward the farm business for additional inputs of labour, management and capital, and compensate for the risk of changes or innovation. This assessment from the viewpoint of private profitability is also important in project design; for example, for the design of a supporting rural credit scheme or the targeting of input subsidies.

Financial analysis may also be extended to appraise projected capital and recurrent costs and revenue streams (cost recovery) for project implementing agencies, rural credit institutions, farmer cooperatives and product processing industries. Similarly, government expenditure on, and receipts from, the project must be explicitly planned for. Inadequate financial planning and management resulting in failure to meet recurrent operating and equipment replacement costs are common causes of poor project performance.

Shadow prices:

The financial analyses summarised above will use prevailing domestic market prices. Using economic cost-benefit analysis, governments seek to allocate capital to promote development by selecting investments that provide the maximum net benefit to society. Public sector investment decision-making is seldom easy. Leaving aside the political factors which can direct resources away from their economically optimum pattern of allocation, there are many issues to be resolved in deciding upon the best use of scarce resources. These include estimation of any externalities of a project (often impacts on ecosystem services), quantifying the future benefits and costs of a project, and the problem that market values may differ from economic efficiency values because of market imperfections or government interventions.

Shadow prices are the trade opportunity costs (i.e. economic values) of project inputs and outputs and may differ from market prices used in financial analysis because of market imperfections and distortions. Economic CBA seeks to avoid investments that are only financially profitable under the distortions that exist, and to select investments consistent with a long-term pattern of efficient resource use (in effect, a country's comparative advantage). Compromises must often be made when policy induced distortions are expected to persist, but the economic analysis will still inform decision-makers about the consequences (and economic costs) of their choices.

In all economic valuation, transfer payments (e.g. taxes and subsidies) should be excluded as they are transfers between parties in the economy and not resource costs.

For most traded goods and services, an appropriate shadow price (opportunity cost) will be the world market price at the border (either the free on-board price (FOB) for exports or the cost, insurance and freight price (CIF) for imports).

Non-traded outputs sold on the domestic market can be valued by what consumers are willing to pay. When project output is relatively small compared to the market volume there should be no change in market price, and this can be taken as the economic value. If project output is large (or if there are significant market imperfections, e.g. a monopoly) estimation of willingness-to-pay requires estimation of a demand curve for the commodity (and is more demanding of data and analytical capacity). Most outputs of SLM projects will be traded, or at least tradable, and can be valued in border prices (directly, on in terms of traded goods for which they are substitutes).

Non-traded inputs for which domestic production will be increased to supply the needs of the project can be valued as the marginal cost of increased production. If the market is undistorted the domestic market price can be used. A more accurate estimation requires a cost disaggregation into traded, labour, land and other cost components.

Non-traded inputs that are in fixed supply are important in SLM projects as this includes labour and land. Labour is valued in terms of its opportunity cost, usually the marginal productivity of workers in the sector from which the labour is ultimately drawn.

Key point! Note that the opportunity cost of a farm family's own labour will usually be accounted for by the with versus without project comparison made at farm level (see for example the analysis in WS3 in the Excel workbook for this case study for Southern State).

Similarly, land is valued in terms of its opportunity cost, usually the net value of production forgone when the use of the land is changed from its 'without' project use to its 'with' project use. This will again usually be accounted for by the comparison of 'with' v 'without project' scenarios.

Terminology:

Usage varies between practitioners and agencies.

We recommend:

- **shadow prices = economic prices = efficiency prices = social prices**
- **financial analysis and financial cost-benefit analysis (for private profitability viewpoint)**
- **economic analysis, economic cost-benefit analysis and social cost-benefit analysis (for economic profitability from a societal viewpoint)**

Note that 'social cost-benefit analysis' also sometimes refers to further methods of cost-benefit analysis in which shadow prices are weighted to take account of objectives for income redistribution and/or economic growth. 'Social' can also have a more general usage in referring to the social fabric of society, i.e. how it is organised, how people interact and how benefits and costs are distributed.

Source: Smith 2019

Ecosystem services identified in Section 3 for Southern State have been valued as follows:

A) Provisioning services

A1: increased crop production from improvements in soil fertility and soil moisture status

The market price valuation method estimates economic values for ecosystem products or services that are bought and sold in actual markets. The economic benefit of greater availability of these products is thus the incremental quantity produced multiplied by the price at which the products sell (less the incremental costs associated with the production). Limitations arise when the true economic value of goods or services is not reflected in market transactions because of market imperfections and/or policy effects. Hence, the possible need for shadow pricing.

Incremental outputs of sorghum, sesame and maize are valued using constant farmgate market prices for each crop as elicited from the household survey. The same prices can be used for the crops for the baseline and SLM scenarios for the project life (25 years), except for sesame for which higher quality and hence higher value production is expected from the better growing conditions created by the agroforestry system from year 4 onwards. Similarly, farmgate prices for tree gum and firewood were elicited in the household survey. Also, the cost to households of purchasing water supplied by water tanker (see data in WS2 in the Excel workbook for Southern State).

CBA explanation: future prices for costs and benefits

The analyst must choose to use constant or current prices in project analysis. Constant prices are set at a point in time, usually the immediate pre-project situation, and are used throughout the project life. Alternatively, the use of current prices requires forecast of prices in future years.

In practice, constant prices are generally used in project appraisal. If constant prices are used throughout the project analysis – for future years as well as the initial year – then resources will be consistently valued at prices reflecting their value in alternative uses now. Future economic effects will be measured in the same units as present effects, and the relative comparison of costs and benefits at any point in time will be valid. Other advantages are that working with constant prices from the base year avoids the need to estimate a rate of inflation and simplifies computations. Most price forecasts for world commodity prices are also expressed in constant terms.

However, if the analyst thinks that, during the lifetime of the project, some prices will rise or fall significantly relative to others, these changes in relative prices should be considered. For example, it may be foreseen that wages will fall relative to the present price for outputs or inputs. In this case, constant prices should be adjusted for this relative price change. Price forecasting is, however, itself very uncertain and precise projections of the general price level and all deviations from it are usually not possible. In most cases, it is reasonable to assume that future price changes will be similar all components of the costs and benefits within a project.

Source: Smith 2019

Key point! In our case studies two relative price adjustments are made as illustrations. For Southern State the price of sesame is increased from year 4 onwards as noted above, because of improvement in product quality in the SLM scenario. And for both Southern and Northern State as noted below, the social cost of carbon is increased annually relative to other prices to reflect the expectation that future emissions produce larger incremental damages as physical and economic systems become more stressed in response to climatic change.

Market prices may be affected by domestic policies including tariffs, subsidies or taxes, and by imperfect competition. Sorghum, sesame and maize are not traded internationally by Eldamia but are bought and sold by many buyers and sellers with little state intervention. Thus, domestic market prices can be accepted as economic values representing societal benefits. Tree gum is a higher value and internationally traded commodity. Thus, for the project level economic analysis the incremental production of tree gum was valued at international parity prices using the Nominal Protection Coefficient (NPC) for production in Eldamia. The NPC is an indicator of the nominal rate of protection for producers that measures the ratio between the average price received by producers at farm gate, including payments or taxes per tonne of current output, and the border-equivalent price (global prices adjusted for costs of transport, marketing and processing) measured at farm gate level. The estimated NPC for tree gum is less than a value of one, indicating that the export value chain in Eldamia gives rise to lower income at farmgate than would be the case in an economy which applies international parity prices.

Changes in supply from the project are also assumed to be too small to affect domestic market prices for the relevant crops and firewood. For tree gum, it can also be assumed that demand for tree gum from Eldamia is perfectly elastic on the world market and therefore additional supplies will not affect world market prices.

B) Regulating services

B1: nitrogen fixation and
B2: soil moisture conservation

Enhancements to these ecosystem services are valued through their contribution to enhanced production as considered above for ‘A1: increased crop production from improvements in soil fertility and soil moisture status’.

Key point! The classification and listing here separately identifies both the provisioning and regulating services enhanced by the SLM strategy, but note that it is important to avoid double counting of benefits in preparing the data sheets and cost-benefit analysis.

CBA explanation: environmental valuation – change in productivity approach

The change in productivity approach can be used to estimate the economic value of ecosystem services that contribute to the production of marketed goods. It is applicable where the ecosystem services are used, along with other inputs, to produce a marketed good. For example, soil moisture as an input to the production of sorghum. The economic benefit of improved soil moisture can be valued in terms of additional revenue from increased, and/or improved quality, farm production. Additional revenues are estimated as the difference in crop yields with and without enhanced soil moisture, multiplied by the unit price of the crop, less any incremental costs of production.

Source: Smith 2019

B3: sediment stabilisation and reduced soil erosion

Valuation of sediment stabilisation and reduction in soil erosion uses an estimate of average annual avoided cost of soil erosion valued in terms of the replacement cost of inorganic fertiliser that would replace nutrients lost. A compound NPK fertiliser (15-20-20) is commonly used in Eldamia. Modelling indicates that an additional 1 kg of NPK fertiliser per hectare would be needed to replace the amount of nitrogen and phosphorus lost from the soil each year pre-project, and thus each year in the baseline scenario. Fertiliser is mainly imported to Eldamia but farmers benefit from subsidies to energy, transport and farmgate price in the supply chain. Hence, the NPC for NPK fertiliser to be used in the study area is less than one (see data in WS2).

CBA explanation: environmental valuation – replacement cost

The replacement cost method assumes the value of an ecosystem service is at least equal to the cost incurred to replace it. The method is thus most appropriately applied where replacement expenditures have been or will be made. It may underestimate the true economic value of the ecosystem service which ideally would be valued in terms of people's willingness to pay for it.

Source: Smith 2019

Key point! Note that the reduction in soil erosion (i.e. soil and its nutrient content saved) each year in the SLM scenario compared to the baseline scenario has been valued and entered as a benefit stream in the SLM scenario in WS4. As an alternative, the value of the loss of nutrients could have been entered as a cost stream in the baseline scenario. Either is possible but not both! Again, it is important to avoid double counting of benefits or costs in preparing the data sheets and cost-benefit analysis.

B4: increased infiltration and reduced runoff

When natural water holes and shallow wells run dry, villagers in the Awasha Basin incur expenditures for water purchase supplied by tankers. Hence, the replacement cost method is appropriate to estimate the value of a higher water table in the shallow aquifer that is used by these communities. It is assumed that the prevailing market price of water purchased is a good proxy for the economic value of shallow groundwater (although a more detailed analysis of price distortions in the supply chain for water supplied by tanker could be justified in practice). It is assumed that the full benefit in the SLM scenario is gained from year 1, which may overestimate this benefit flow in the early years of the project.

C) Supporting services

C1: carbon sequestration

Enhanced carbon storage is valued as the damage costs of climate change impacts that would be avoided by reducing carbon dioxide emissions each year. These damages include decreased agricultural productivity, impacts of rising sea levels and harms to human health. Social cost of carbon (SCC) estimates reported by the US EPA are used for this. SCC values are estimates of the damage associated with climate change impacts that would be avoided by reducing carbon dioxide (CO_2) emissions by one metric ton in a given year. SCC estimates are assumed to increase over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change.

CBA explanation: environmental valuation – avoided damage expenditure

The avoided damage method assumes the value of an ecosystem service to be at least the costs incurred to avoid damage from loss of the service. Thus, it is most appropriately applied where damage avoidance expenditures have been or will be made. It may underestimate the true economic value of the ecosystem service, which ideally would be valued in terms of people's willingness to pay for it.

Source: Smith 2019

Non-valued benefits and costs for the Southern State study

For the agroforestry and reforestation components the fodder and browsing value of A. specialis to livestock is not included because browsing pressure reduces tree gum production. Farmers must choose whether to use the trees for gum or fodder. Given low livestock populations and demand for fodder in south-western Eldamia it can be assumed that farmers will usually favour gum production.

The seed production value of A. specialis was also not included. The value of this service is negligible relative to the value of gum production and other ecosystem services.

As noted above, the provisioning services of trees planted on hills (reforestation component) have not been valued because the common land ownership situation leaves it unclear who will harvest these benefits, how consistently they will do so and at what cost. Any contribution made by increased tree cover to sustained or improved biodiversity was also not valued. The trees are only valued, as described above, for their contribution to shallow aquifer recharge and carbon sequestration acknowledging that this may underestimate their total value.

Cultural services and impacts have not been valued.

CBA explanation: the relevance of economic valuation

The methodology for economic CBA was developed over 40 years ago in a different economic environment to that prevailing today. Market liberalisations have reduced trade distortions and the role that governments play in the supply chains of many goods and services. Some economists argue that this allows market prices to sufficiently reflect opportunity costs, thereby eliminating the need for shadow prices.

Some significant distortions and market failures do, however, still exist and it remains appropriate to selectively use shadow prices where their values are material to CBA outcomes. In contrast, project externalities, notably environmental impacts, were often neglected in the past, but are now recognised as the major source of divergence between private and social (economic) values. As illustrated in this case study, environmental valuation methods now provide a means to address this and to seek to fully include values of change in ecosystem services in an economic CBA.

Thus, economic CBA enhanced by environmental valuation can be complementary to market liberalisation and policy reform and continue to help select economically efficient project designs and investment decisions.

Source: Smith 2019

Key point! Note that in this Southern State case study shadow prices are used for the traded output, tree gum, and for the traded farm input, NPK fertiliser.

4.3 Section summary

In this section ecosystem services for the Southern State study area have been valued, usually on a per hectare and per year basis. Data sources and relevant data have been summarised. The relevant data is shown in WS1 and WS2 in the Excel workbook for Southern State.

It is important to recognise and take note of benefits or costs which may not have been quantified and valued so far because of a lack of data or for other reasons. Such omissions should be kept in mind when the results of the CBA are interpreted in Sections 6 and 7 below.

Explanations of key concepts in economic CBA have also been provided in this section. Refer to these as you need to as you proceed through the remainder of this module.

CHAPTER

05

ELD step 5 Land degradation patterns and pressures and scenarios

Activity 4: Read Section 5

Section learning outcomes

- Understanding the importance of identification of land degradation patterns, and drivers and pressures on the sustainable management of land resources;
- Further understanding of how to develop alternative scenarios for cost-benefit analyses;
- Appreciation of the need for iterative review and revision of previous steps as needed to ensure the assessment is as comprehensive as possible.

Section 2.1 above described land degradation patterns and pressures.

As you read this section, again assess how the data for the cost-benefit analysis (CBA) has been entered and presented in the Excel worksheets WS1 and WS2 for pre-project, baseline and SLM scenarios.
You might want to refer to the modules on the ELD steps and on CBA within the ELD Campus again to understand the background behind scenario development for CBAs.

5.1 Valuation scenarios to be analysed

Southern State:
Baseline scenario: 'business as usual' consisting of no significant trend (i.e. no change) in land degradation

↓ ↓ ↓

Future scenario: investment made, and reduced land degradation and improved ecosystem service provision achieved.

The baseline scenario assumes that the current landscape configuration and soil conditions will not change, and that the average annual weather pattern of the last 20 years is the best predictive value for the baseline and future scenarios. The future scenario concerns implementation of a SLM strategy consisting of:

i) introduction of A. specialis-based agroforestry in flatland cropped areas,
ii) reforestation of barren hills, and
iii) terracing of some cultivated slopes to increase soil fertility and crop yields.

The assumptions adopted for the baseline scenario can be considered conservative (i.e. likely to underestimate the net benefits of the SLM scenario compared to the baseline scenario). Given past degradation trends it would be reasonable to assume that the current landscape degrades further rather than remaining unchanged. However, for this location, it is difficult to predict future changes and because the landscape is already badly degraded, further degradation may not be rapid. It is also difficult to predict future changes in climate but comparison of the baseline versus SLM scenarios is possible with the assumption that both are subject to the same weather parameters. Decision-making should, however, take into account as far as possible that each scenario could be affected differently by change in climate over the 25-year time horizon adopted.

5.2 Section summary

Information in this section is limited for this fictional case compared to that which would be provided in an actual case study. In developing scenarios for comparison using cost-benefit analysis it is important to as objectively and accurately as possible identify land degradation patterns and their drivers, and the opportunities and constraints for more sustainable management of land resources. This includes assessment of how land resources and factors causing degradation are distributed spatially and between households or groups. Similarly, how drivers of adoption of sustainable land management (including the role of property rights, legal systems and formal and informal institutions) may vary spatially, between households and within households (e.g. gender differences).

ELD step 6 Cost-benefit analysis (CBA) and decision-making

Section learning outcomes

- Understanding of how CBA (ex-ante appraisal of economic viability) can be used to compare the costs of adopting a sustainable land management practice against the benefits derived from it, thus informing the assessment of sustainable land management options that can reduce or remove land degradation pressures;
- Practice in completing a CBA for comparisons between costs and benefits across different scenarios, and specifically for a 'SLM' scenario compared to a 'business-as-usual' scenario to assess whether the proposed land management changes lead to net benefits;
- Understanding of how use of CBA can help assess options for the location, scale of intervention, alternative technologies and implementation approaches, including economic incentives and other policy instruments to promote sustainable land management, so as to help identify the most economically efficient and sustainable practice for a given scientific, political, legal, cultural, or social context;
- Understanding of how to treat risk and uncertainty, including recognition that optimal scenarios can provide a guide but may be based on unachievable assumptions in practice, e.g. for land user adoption rates or regarding barriers to implementation.

This section is divided into the following steps in completion of a CBA:

1. Definition of the timeframe for analysis, identification and categorisation of benefits and costs (from ELD steps 3 and 4 above) and choice of discount rate.
2. Calculating an annual incremental net benefit stream under alternative scenarios.
3. Deriving measures of project worth, i.e. economic indicators of whether an investment is worth undertaking (including net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR)).
4. Undertaking a sensitivity analysis to assess impacts of uncertainty.

Also read the following boxes as you progress through this section:
CBA explanation:
project life and discounted cash flow analysis
CBA explanation:
measures of project worth

You might want to refer to the module on CBA within the ELD Campus for explanations on discounting and indicators of a project worth.

Activity 5:
Read Section 6

6.1 Timeframe for CBA and discount rate

For the study area and projects in Southern State a project life of 25 years has been adopted. In the absence of other determining factors, this is primarily based on the economic life of the A. specialis trees to be planted in the agroforestry and reforestation components of the SLM strategy for Southern State.

For the discount rate, benchmark interest rates for Eldamia have fluctuated between 5 and 6% over the last five years (the minimum rate of return investors will accept for buying non-government securities). For financial farm level analysis, a discount rate of 8% was used to reflect that some investors will demand a higher rate of return for investment in projects subject to natural risks.

Private discount rates are generally considered to be an upper bound for public projects in Eldamia because rates of return to public sector investments are usually lower than for the private sector. **A discount rate of 5% was thus used for economic analysis** (this is also in accord with recently issued US guaranteed Eurobonds, frequently leveraged to finance government spending in Eldamia).

Benefits and costs for the projects were identified and categorised in Section 3 above, and information for their valuation compiled in section 4.

Key point! Note how worksheets WS3 and WS4 are laid out with values for benefits and costs entered in rows for each year of the 25-year project life as denoted in the columns. Also, that values for the discount rate are entered in WS2 for use in calculation of NPV and benefit-cost ratio values in WS3 and WS4.

CBA explanation: Project life and discounted cash flow analysis

Project life:

Timing matters, and when costs and benefits occur may be just as important to the decision maker as how valuable they are. All SLM projects will vary in their initial investment costs and scale, in the amount and timing of costs and benefits in following years and in their overall lifetime. Discounted cash flow analysis is used to make such different cost and benefit flows comparable.

Determination of the project life can be somewhat arbitrary, but it is essential to bound the project analysis in time. The following should be considered in choosing the project life:

- the effective working life of any major capital equipment or capital assets created before rehabilitation, repair or replanting will be necessary, e.g. life of trees planted, terraces constructed or small dams before their siltation,
- the first year and the last year in which the project will yield benefits,
- national planning objectives and budgetary timeframes.

In many SLM projects it may be that the project's benefits are expected to continue indefinitely, but the time boundaries of economic analysis are often kept shorter than technical estimates of the project's physical life. When discounting is used, costs and benefits occurring more than 15 years into the future become relatively less significant and, when more than 30 years ahead, have almost no influence on the results. Within the project life chosen, the analyst must determine when actual costs and benefits will occur on an annual basis.

Discounted cash flow analysis:

The procedure of discounting is used to take account of the time value of money, which is based on two things. First that individuals and society prefer consumption sooner rather than later (related to the assumption that the marginal utility of income/consumption diminishes over time if we expect to be richer in future). Second, that money invested in a project has an opportunity cost (the marginal productivity of capital) because an alternative investment (or saving opportunity) usually exists which will generate a return in future.

The **compounding method** determines the future value of a present amount growing at a certain interest rate:

$$A = P\,(1+r)^t$$

Where:

A = amount to which the investment grows (the future value)
P = principal invested (the value today)
r = interest rate
t = time in years (or other time periods)

The **discounting method** determines the present value (PV) of a future sum:

$$PV = A/(1+r)^t$$

Where:

PV = the present value
A = the amount of the future sum being evaluated
r = discount rate
t = time in years

Hence, discounting is the inverse of compounding, and applies a weight to the costs or benefits (or incremental net benefit) in different years to convert them to a common basis (i.e. their present value). These calculations are simple and can be readily programmed into commercially available computer programmes, such as spreadsheet software. Indeed, such software typically includes pre-programmed functions for this.

Discount rate:
The choice of the discount rate to be used in project analysis is important because costs and benefits are not usually spread over time symmetrically. Typically, the main costs occur early on with the main benefits following later. The higher the discount rate, the lower the present value of later benefits compared to earlier costs.

For financial analysis:
For analysis of private profitability, the discount rate should, as a minimum, be the cost of borrowed funds. This is to ensure that the project/investment will generate resources in future at a rate that will allow repayment of all borrowings. In practice, investors may require higher returns on the equity proportion of financing (i.e. their own capital invested rather than borrowed) if alternative projects or saving opportunities offer more attractive returns and/or add an allowance for risk.

(The cost of borrowing should be expressed in real terms when the project cash flow is drawn up in constant prices. When there is more than one source of borrowed funds, a weighted real cost of borrowing can be calculated).

For economic analysis:
The 'perfect' discount rate would arise in a 'perfect' capital market where the interest rate would equal both the rate of return on an additional project (marginal productivity of capital) and the income savers require to compensate them for foregoing immediate consumption (time preference or the consumption rate of interest).

But in reality, capital markets are imperfect and even perfect market rates of interest may be considered too 'short sighted' if based on the aggregate preferences of individuals rather than the values of society (given that society has no risk of death and may be expected to act 'paternalistically' for the interests of future generations). Society's time preference is thus a subjective value and is not directly observable from actual capital markets.

In practice, the conventional approach is to choose a discount rate for economic analysis to reflect the opportunity cost of committing investment funds to a new project. The usual assumption is that the public investment budget is fixed over a given time period and emphasis is placed on the use of the discount rate as a rationing device to screen public projects competing for limited funds. Thus, the discount rate for economic cost-benefit analysis should be an estimate of the marginal rate of return to investment in the economy, valued in economic prices. (Alternatively, if the investment budget is not limited, the discount rate may be taken as the cost of additional borrowing from domestic or foreign sources). The discount rate for economic analysis is a national economic parameter that should be used consistently for all project appraisal.

This conventional approach typically results in the use of relatively high discount rates (5–12%). However, it can be argued that in developing countries capital productivity should be high as a result of capital scarcity and/or human resource and infrastructural constraints to the capacity to absorb investment. Also, that the rate of time preference is high because poor and vulnerable people must trade-off immediate survival needs versus long term food/income security.

Relatively high discount rates will systematically bias investment decisions in favour of project alternatives with lower initial costs and/or a shorter gestation period before benefits are generated.

This may not favour investments in SLM that inevitably require time, even decades, to reverse land degradation.

Use of relatively high discount rates may also bias technical choices in the design of the project. For example, given similar establishment costs, early yielding annual crops may be preferred to slow maturing perennial crops. Designs with lower initial capital costs may be chosen, although these may often have higher recurrent costs. For example, unlined irrigation canals that need annual maintenance, compared to canals lined with concrete. The higher future recurrent cost burden that results may also have implications for the sustainability of the infrastructure or service being provided.

Discounting convention for project analysis:
Different analysts and development agencies apply different conventions as to whether costs and benefits should be discounted beginning with the first year or with the second year of the project. This has implications for present values calculated which will differ between both cases.

Convention 1): the first year of a project is designated as 'Year 0', in which investment is made, no benefits occur, and no discount factor is applied (this matches the assumption that the main investment is paid 'up front' and should not be discounted in value).

Convention 2): the first year is designated as year 1, any costs or benefits may be incurred, and all will be discounted for year 1.

Convention 2) is most commonly adopted in development project appraisal and is used in this self-study module. It is convenient to use the same time reference for project years as discounting periods. It is also realistic for SLM and other development projects that investment and other costs are paid out throughout the first year and not all at the beginning. Therefore, their present value after time has passed will be less than their face value as budgeted at or before project commencement.

(Allowing for discounting for shorter than one year periods would be complicated and add only marginal precision to the analysis outcomes. However, if the timing of investment and other costs in the early years of a project is significant, which it may be at smaller scale, for example for farms, then adjustment can be made. This is usually achieved by making entries in the cash flow for 'incremental working capital' which can simply be regarded as adjustment to the timing of entries for costs) (for more information see Gittinger, 1992).

Source: Smith 2019

6.2 Calculating an annual incremental net benefit stream under alternative scenarios

Please refer to WS3 in the Excel file

Southern State
Financial analysis is first conducted at the farm level for the flatland farms (agroforestry component) and then for the hillside farms (terracing component). The objective is to assess the financial viability of the SLM interventions at farm level. Financial analysis of the reforestation component is not necessary because there is no clearly defined private ownership for benefits (or costs).

Note that the tables in WS3 effectively consist of a series of annual farm budgets that compare benefits and costs in each year for both the baseline scenario and the SLM scenario. The net benefit (benefits minus costs) in the baseline scenario is then deducted from the net benefit in the SLM scenario to provide the annual incremental net benefit stream. This achieves the 'with' versus 'without' project comparison year by year (even though for this component the baseline scenario remains unchanged over time). By correctly analysing the incremental costs and benefits of the SLM scenario it also provides the best way to account for the opportunity cost of the farm family's own labour and their land as employed in the baseline scenario. In the SLM scenario any additional labour costs, e.g. for tree pruning and harvesting, are also accounted for as entered in the worksheets.

Exercise 4: Completing benefit and cost streams

a) Using the data already entered in WS1 and WS2 (Excel file), enter formulae in WS3 to calculate the annual value of sorghum production for a flatland farm in the baseline scenario (cells B6 to Z6).
This will be area planted x yield x price.
Answer guideline: see box at the end of this chapter 6- after the section summary

Key tip! When the same formula is needed in each year it is time consuming to repeatedly enter it in each cell. If there is no change in the formula you can copy and paste it from one cell to another (i.e. one year to the next). But this is where the difference between 'relative' and 'absolute' cell references is important. By default, a cell reference is a relative reference, which means that the reference is relative to the location of the cell. When you copy a formula that contains a relative cell reference, that reference in the formula will change. But for the value of a price first entered in WS2 for example, you may wish to keep the cell reference and hence value the same. If you want to maintain the original cell reference in your formula when you copy it, make the cell reference 'absolute' by preceding the column (e.g. B) and row (e.g. 6) with a dollar sign ($). Then, when you copy the formula from one cell to another it stays unchanged, picking up the data values that you need for your calculation.

Key tip! Also try placing your cursor just before the column letter in the formula in the edit bar. Press the F4 key and Excel will add the dollar signs for you.

Key tip! Note that in preparing your benefit and cost streams over several years you may still need to make changes in the formula if the underlying data changes over time as set out in your first data sheets (here WS1 and WS2). In our case study this is the situation, for example, for some yield data in the SLM scenario.

b) Enter formulae in WS3 to calculate the annual value of tree gum production for a flatland farm in the SLM scenario (cells F17 to Z17).
Answer guideline: see box at the end of this chapter 6- after the section summary

c) Enter formulae in WS3 for the SLM scenario for Tree planting cost (B22) and for Tree cutting for firewood cost (Z25)
Answer guideline: see box at the end of this chapter 6- after the section summary

Study the incremental net benefit stream (row 29 in WS3). Do you think this is attractive to farmers and provides them with incentive to participate in agroforestry? (We will return to this question).

And what about the hillside farms. Do you think the incremental net benefit with the SLM scenario (row 55) is attractive to farmers? Will they terrace their farms?

Key point! WS3 consists of farm level analysis and data is calculated and presented per farm. Layout and data presentation are a choice for the analyst but obviously coherence and logical consistency must be maintained.

Please now refer to WS4 in the Excel file

Economic analysis is conducted at the project level in WS4. Each of the three SLM strategy components – agroforestry, reforestation, terracing – is analysed in turn.

Key point! WS 4 consists of project level analysis. Values are shown per hectare. This is a choice by the analyst but again coherence and logical consistency must be maintained

As this is project level analysis and from the economic or societal viewpoint, additional benefits and costs are included to those considered at farm level.

For the agroforestry component, in WS4 note that row 6 takes farm incremental net benefit from WS3 but as a value per hectare. This takes account of the baseline scenario (i.e. the without project situation). Hence, the net value of production (farm benefits less farm costs) in the baseline scenario is accounted for. The additional benefits from enhanced ecosystem services that benefit society as a whole and not just the farmers are then included in rows 7 to 9. And project level incremental costs for implementation are set against these in rows 12 to 13.

But what about any need for shadow pricing? Note that compared to WS3, row 6 includes an adjustment from years 5 to 25. This applies the NPC for tree gum to its farmgate price. In other words, the private farm level analysis in WS3 uses the domestic farmgate price, whilst the economic analysis in WS4 uses the shadow price.

In WS4, study the tables for each component of the SLM strategy and make sure you understand how they have been constructed. Re-read the points above if necessary.

6.3 Deriving measures of project worth

Please refer to WS3 and WS4 in the Excel file

Calculating NPV, IRR and BCR:
Three measures of project worth have been calculated in worksheets 3 and 4 (WS3 and WS4): net present value (NPV), internal rate of return (IRR) and benefit-cost ratio (BCR).

CBA explanation: Measures of project worth

Net present value (NPV):
Also known as net present worth. This is the best discounted measure for use in project analysis.

There are two ways to calculate NPV:

1. subtracting the total discounted present value of the cost stream from that for the benefit stream,
2. discounting the incremental net benefit stream.

Both methods give the same result, but the latter is most commonly used in project analysis. The advantage of this procedure is that it makes no difference at what point in the calculation the netting out of costs and benefits takes place.

The formal selection criterion for the NPV measure is to accept all projects with a NPV of zero or greater when discounted at the chosen discount rate.

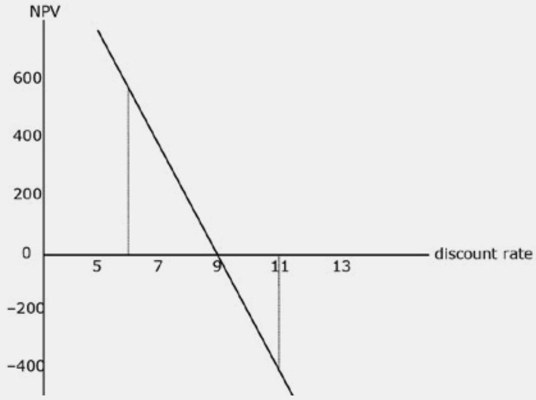
However, no ranking of projects is possible using the NPV criterion because the value obtained is an absolute, not a relative measure. For example, a small, highly attractive project may have a smaller NPV than a large, marginally acceptable project.

Internal rate of return (IRR):
The IRR is the maximum interest rate that a project could pay for the resources used if the project is to recover its investment and operating costs and still break even. It is thus the discount rate which will make the NPV of the incremental net benefit stream equal zero.

The formal selection criterion for the IRR measure is to accept all projects which have an IRR equal to or greater than the chosen discount rate.

The IRR cannot be calculated directly, and it is necessary to follow a procedure of iterative estimation to find its value.

(If calculated by hand, use linear interpolation to find the discount rate for which NPV=0 between two rates, one resulting in a positive NPV and one a negative NPV. For example, in the figure below interpolating between a discount rate of 6% and 11% indicates that the IRR is approximately 9%. The relationship is actually a curve and not a straight line and hence there is a margin of error using this method).



One disadvantage of the IRR is that it cannot be calculated if every year of the project generates a positive incremental net benefit. At least one negative value for incremental net benefit is needed.

The IRR can also have more than one solution when there are relatively large negative incremental net benefits in later years of the project. This may be unusual but could occur, for example, the costs needed to decommission a large dam or nuclear power plant.

The benefit–cost ratio (BCR):

The BCR is the ratio obtained by dividing the present value of the benefit stream by the present value of the cost stream (employing a consistent convention for 'netting-out' of benefits and costs).

The formal selection criterion for the BCR is to accept all projects which have a ratio of one or greater when the costs and benefits are discounted at the chosen discount rate.

This method has the disadvantage that the value of the ratio will change depending on where the 'netting out' in the cost and benefit streams occurs. The process of subtracting costs from benefits to obtain the net benefit must be done in the same way for all projects if we wish to compare BCR values for different projects. For example, the ratio could be based on comparison of the present worth of gross benefit to the present worth of gross cost. Alternatively, the present worth of a measure of net benefit (gross benefit less non-project specific production and distribution costs) could be compared to the present worth of project-specific costs (i.e. capital and recurrent costs for the investment made). These two alternative approaches would return different values for the BCR.

Use of these measures of project worth:

The decision for a single project is straightforward. Using the same information and assumptions each of the three criteria should give the same project decision.

NPV is particularly useful when an array of projects is to be financed from a fixed amount of money. Given the chosen discount rate, the NPV helps identify projects that will maximise net benefit. The NPV is thus the preferred criterion for choosing between mutually exclusive projects. It should thus also be used for choosing between alternative designs and technical options for the same project. The IRR is intuitively more appealing, and the results are easier to communicate, but this measure has the limitations noted above. When ranking mutually exclusive alternatives, a ranking of IRR values may be inconsistent with the ranking of NPVs, and NPV is to be preferred for the reasons given above. The BCR is generally considered inferior to NPV and IRR as a criterion to assess project worth because of its sensitivity to the way costs and benefits are classified (or 'netted-out').

Source: Smith 2019

Exercise 5: calculating measures of project worth

1. Enter formulae in WS4 to calculate the NPV, IRR and BCR for the agroforestry component (cells C16, C17 and C21). If you are not familiar with the formulae needed see the other examples already calculated in WS3 and WS4 and the guide immediately below.

Excel formulae:
for NPV, enter:
=NPV (cell containing discount rate, range of cells for incremental net benefit stream)
for IRR, enter:
=IRR (range of cells for incremental net benefit stream, cell containing discount rate)
for BCR, enter:
NPV for incremental benefits / NPV for incremental costs
Answer guideline: see box at the end of this chapter 6- after the section summary
How do you interpret each of the NPV, IRR and BCR values calculated in WS3 and WS4? (We will return to this below).

Interpreting NPV, IRR and BCR values

Please refer to WS3

For the flatland farms under the agroforestry component in Southern State: the positive NPV value, IRR greater than the relevant discount rate (8%) and BCR value greater than one, all indicate that the investment in agroforestry by a farmer is financially viable. In other words, the costs of agroforestry adoption are outweighed over 25 years by the benefits of better crop yields and quality, plus the value of harvested tree gum (and firewood).

At face value this should provide incentive for farmers to make this change in their farming system. However, the analyst should also inspect the pattern of the incremental net benefit stream (row 29). Note that the farm household will be significantly worse off in the first three years compared to the baseline scenario. Can they rely on their own savings to meet this gap? Can they reduce their household consumption? Unlikely! Will there need to be credit provision to enable them to make this investment?

Thus, the outcomes of the CBA provide information, but not all the answers. The information should inform decisions on whether and how to proceed. In other words, how implementation of the project can be best designed.

What is your interpretation of the outcomes for the hillside farms (terracing component)? Are incentives enough that farmers can be expected to participate in terracing their plots? Will assistance in the form of a credit scheme be needed? Will such a scheme need to be specifically designed to meet the needs of rural women? What other factors may influence the technology adoption decisions made by such farmers?

Please refer to WS4

Consider the NPV, IRR and BCR values for the three SLM strategy components: agroforestry, reforestation and terracing.

Project level economic analysis, comparing all valued costs and benefits from the viewpoint of society, shows each component to be a viable investment that can be selected for implementation if the necessary funds are available. If we had to choose between them, we should first recommend the agroforestry component because it generates a higher NPV per hectare.

As noted above, this analysis (WS4) has been completed on a per hectare basis. This is deemed appropriate and useful for many SLM interventions to aid decision making and plans for scaling up. For example, rows 23 to 26 in WS4 indicate NPV and IRR outcomes for a 500-hectare pilot project for agroforestry. Note that with increasing scale the NPV increases but the IRR remains unchanged. Thus, an actual project could be planned at the scale deemed feasible and affordable.

Key point! Note that depending on scale and implementation constraints, some refinements to the analysis shown might be needed. For example, it may not be possible to achieve 500 hectares of agroforestry planted in one year. Hence, more detailed predictions of how implementation and benefit generation would be phased over the first few years of a scaled-up project may be needed. And consequent changes in the timing of costs and benefits will affect NPV and IRR outcomes.

6.4 Undertaking a sensitivity analysis to assess impacts of uncertainty

So far, the financial and economic appraisals of SLM projects have been based on the use of single-valued measures. The prices and quantities of costs and benefits used are the best estimates available or, in other words, the most probable values. However, costs are frequently underestimated, crop yields overestimated, implementation time underestimated and plans are disrupted by unforeseen weather events, and so on.

There is no perfect solution to the problems of inadequate data and uncertainty about future events and outcomes. As a minimum the analyst should undertake sensitivity analysis.

CBA explanation: Uncertainty and risk

Uncertainty can be defined as a situation regarding a variable in which neither its probability nor its actual value is known. For example, if you are uncertain about price projections you neither know how prices will change nor the probability or likelihood that they will change.

Risk can be defined as a situation in which the probability distribution of a variable is known but its actual value is not. Therefore, you would know the probability of each of a range of prices occurring, but you would not know what the price is going to be.

Uncertainty is inherent because the project analysis is based on predictions of the 'with' and 'without' project situations over time, relying on input and output data which may at best be estimates derived from past trends, expert experience and models. Single value decision criteria such as NPV and IRR can give the impression that the analysis is a precise and certain quantitative procedure, whereas given the high degree of variability in data used, such an impression may well lead to poor investment decisions.

Sensitivity analysis is concerned with testing the impact of likely variation in the project data. It involves consideration and analysis of the effects of possible changes in any of the key variables that may affect the project outcome. Each sensitivity analysis must be undertaken separately to estimate the effect of a change in assumption or value on the worth of the project, and then a judgement must be made about how likely that change will be.

A common approach in sensitivity analysis uses **switching values**, best defined as the value a variable would have to reach for the project NPV to become zero. Switching values can be used to identify which variables have a significant influence on project outcome and may be presented to facilitate judgments about whether such variables may fall or rise to the critical level.

Based on knowledge of past variation the analyst should identify key variables to test and determine a reasonable range of alternative values to use for sensitivity testing. For SLM projects a checklist of the likely important variables might include the following:

- capital costs
- operating costs
- physical yield or conversion ratios, e.g. land productivity, carbon sequestration rates
- price forecasts for important inputs and outputs
- the time frame for project implementation
- key government pricing, fiscal, trade and exchange rate policies.

A common mistake is to use a standard 5% to 10% variance for two or three factors, such as prices of finished products and cost of raw materials, rather than examining past trends to determine what percentage variations are most likely. For example, the price of some agricultural commodities can vary by plus or minus 50% in a few months, whereas the cost of electricity has tended to be very stable in most countries.

This is relevant to the communication of results to decision makers. For example, compare the usefulness of the information provided in the following two statements for an irrigated rice scheme for which the IRR in the base case (i.e. using best estimates for all variables) is 15%.

a) A fall in the price of rice by 10% reduces the IRR to 12%.
b) The switching value for the CIF price of rice is $80 per tonne, a value 26% lower than that used in the base case scenario. Over the last five years this price has fallen to this level or below on four occasions, remaining at or below $80 per tonne for a total period of 16 weeks.

Sensitivity analysis should also be used to enhance project design and implementation. For example, by:

1. establishing the variation permissible in important cost items without the project running into budgetary difficulties.
2. Optimising allocation of time and resources to data collection and preparation for the variables of most significance in the appraisal; identifying design options that should be considered in detail and areas where most information is required.
3. Highlighting potential problem areas in implementation and/or construction.
4. Identification of variables for risk analysis.

Sensitivity analysis becomes less useful when no variable tends to affect the project significantly on its own and hence critical factors cannot be individually isolated, or when variables are mutually interdependent so that they cannot meaningfully be varied one at a time.

Also, for any SLM projects which involve relatively low capital investment compared to annual variable or recurrent costs, the NPV can be very sensitive to changes in annual benefits and costs. The results of CBA and sensitivity analysis must be interpreted carefully for such projects.

Risk analysis is concerned with estimating the probability of a range of alternative outcomes and assessing the acceptability of this probability of occurrence.

Risk analysis (or probability analysis) in principle assigns a probability of occurrence to each of the possible values of key parameters so that a probability distribution of the range of possible values for NPV (or IRR etc.) can then be estimated. From this, the expected value of NPV and its variance can be calculated. Risk analysis is used in conjunction with decision-making criteria concerning risk, e.g. a criterion might be to accept a project if the probability of the project's NPV falling below zero is less than 10%. In practice simulation trials are run on computer, which allows the consideration of many variables and their probability distributions and estimates the probability distribution for NPV or other measures of project worth.

Source: Smith 2019

Key tip! Once the format of the appraisal has been set up and the decision criteria calculated once using a spreadsheet programme, the whole analysis can be recalculated immediately with a new data value or assumption. The actual sensitivity testing should proceed by changing one variable at a time and recording the outcome associated with each change. Remember, use of your spreadsheet model in this way can only be done if you only entered raw data values once and then used formulae for all calculations.

Exercise 6: Sensitivity analysis for the SLM scenario

Answer guidelines are given at the end of this chapter- after the section summary!

For the agroforestry component:

a) What is the effect for the NPV in the SLM scenario (cell C16 in WS4) of:
   - grain sorghum yield that is 30% lower than the baseline scenario in years 1 to 3 (rather than 20% lower)? (Tip: change the value in cell B23 in WS1) Then return the value to 20% lower.
   - grain sorghum yield that is 5% higher than the baseline scenario in years 4 to 9 (rather than 15% higher)?
   - grain sorghum yield that is 5% higher than the baseline scenario in years 4 to 9 (rather than 15% higher) and grain sorghum yield that is 10% higher than the baseline scenario in years 10 to 25 (rather than 28% higher)?

   What do you conclude?
   Now restore all the original values before proceeding to question b) below.

b) What is the switching value for the price of sesame in years 4 to 25 in the SLM scenario? (Tip: change value in cell E12 in WS2 until the NPV equals zero).

Key tip! To find switching values try out the 'Goal seek' function in Excel. Depending on your version of the software and add-ins you may find this under the 'Data tab' and 'What-if analysis'. It allows you to name the cell containing the NPV calculation to be set to zero by change in the value of another chosen cell.
(Restore original value).

c) What is the switching value for the cost of the extension campaign to promote agroforestry in year 1 per hectare? (Change value in cell E55 in WS1, but answer appears in cost per hectare, i.e. cell E56).

For the reforestation component:

d) What is the switching value for the social cost of carbon (SCC) in year 1 in the SLM scenario? (Change cell E20 in WS2).
e) What is the switching value for the cost to EFS of planting trees per hectare on the barren hills? (Cell E71 in WS1).

For the terracing component:

f) What is the switching value for the price of maize in the SLM scenario for the economic analysis per hectare (WS4)? (Cell E13 in WS2).
g) How does this compare to the switching value for the price of maize for the farm level analysis (WS3)?

Key point! What is the switching value for the discount rate used in the economic analysis?
No need to calculate this as it will be the same value as the IRR!

6.5 Section summary

Section 6 has been a key section for this module. It has taken you through the main steps of cost-benefit analysis for a SLM project, as illustrated by the Southern State case study from Eldamia.

You should have learnt how to layout a CBA using a spreadsheet and how to analyse a project from different viewpoints. In this case the farmer viewpoint (private) and society's viewpoint (economic). You should have gained understanding of the key principles and practice of cost benefit analysis. Data and spreadsheets can be prepared and laid out in many ways, but the principles and logic of CBA must be consistently applied, particularly comparing with and without project scenarios, to avoid important omissions or double counting.

Finally, you have learnt how a spreadsheet-based CBA can be used as a model of the project for sensitivity analysis and testing of relationships between key variables and the project outcomes. This can be used to assess uncertainty, and to compare different design choices for the project.

Solutions to the exercises in this chapter:

Exercise 4:

a) *the calculated values shown in your worksheet should be cells B6 to Z6 – 78000 ES*

b) *Answer guideline:* *cells F17 to K17 – 2625 ES*
cells L17 to U17 – 9188 ES
cells V17 to Z17 – 5250 ES

c) *Answer guideline:* *B22 – 22805 ES*
Z25 – 15203 ES

Exercise 5:

Answer guideline: the calculated values of a project worth shown in your worksheet should be:
cell C16 - 24156
cell C17 - 22%
cell C21 – 3.7

Exercise 6:

Answer guidelines:

Agroforestry component:

a)
- *NPV (cell C16 in WS4) declines from 24156 to 23412 ES*
- *NPV declines from 24156 to 22959 ES*
- *NPV declines from 24156 to 19526 ES*
- *The outcome of the CBA for the agroforestry component is not highly sensitive to variation in predicted grain sorghum yields in the SLM scenario. The project design is quite robust with respect to this single aspect.*

b) *Switching value for the price of sesame in the SLM scenario is 6.6 ES/kg. A price 74% lower than the best estimate for the analysis. Such a fall in price may be very unlikely but not impossible for a cash crop. The likelihood of this may need more investigation.*

c) *Switching value for the cost of the extension campaign to promote agroforestry in year 1 per hectare is 30943 ES/ha. This is more than 5 times greater than the original best estimate.*

Reforestation component:

d) *Switching value for the SCC in year 1 is 176 ES/tonne CO_2 for the reforestation component. This is about 59% of the best estimate value used. Carbon sequestration is the main benefit of the reforestation component, and its outcome is hence quite sensitive to this key value.*

e) *Switching value for the cost to EFS of planting trees per hectare on the barren hills is about 64700 ES/ha. An increase of about 60% compared to the best estimate.*

Terracing component:

f) *Switching value for the price of maize in the SLM scenario for the economic analysis is 2.87 ES/kg. Thus, a fall in the farmgate price of maize of only 4 to 5% will be sufficient to tip this project component into non-viability in economic terms. Although this is not surprising given the additional costs of terracing and that increased maize production is the only ecosystem service that has been valued as a benefit.*

g) *Switching value for the price of maize for the farm level analysis is 2.86 ES/kg. Farmers and the project managers face a similar level of risk for this variable.*

ELD step 6+1

Take action: Policy making and adoption of practices

Activity 6:
Read Section 7

Section learning outcomes

- Understanding of how to interpret the results from CBA to raise awareness and influence policy and investment decision-making, including interpretation of the policy implications of differences between private and social outcomes.

7.1 How CBA results can inform action

The final step in the ELD approach is the implementation of the most economically desirable options by private actors and public decision-makers. The outcomes of CBA are thus important to both land users and policymakers (society as a whole).

For the SLM strategy for Southern State, **both the agroforestry component and terracing component have been predicted to achieve positive NPV values** for flatland farms and hillside farms respectively (WS3). Agroforestry and terracing (like other SLM practices) involve upfront costs as well as changes in cropping patterns and loss of productive area. **Net returns to the new farming systems are initially lower than in the baseline scenario**, but for flatland farms agroforestry improves soil fertility and soil moisture and for hillside farms terraces improve growing conditions for the main crop of maize. For the farming

systems modelled here, for flatland farms benefits exceed costs three years after planting trees, and from year 11 onwards net benefit for farmers increases by almost 25% compared to the baseline scenario. For hillside farms, benefits exceed costs one year after constructing terraces, and net benefit increases by almost 19% from year 3 onwards. **Agroforestry also helps improve farmer livelihoods by providing much needed off-season income**, and the more productive soils improved by agroforestry and terracing may help farmers improved output quality and/or diversify into higher value crops. **Given technical assistance, and possibly assistance with credit to finance the first years of change, it can be expected that farmers will participate in the schemes** in order to benefit from the predicted benefits of more sustainable land management.

For the agroforestry and terracing component, the **project-level CBAs also result in positive NPVs indicating that after taking account of the additional project level costs and benefits** (ecosystem services) that accrue more widely in society in the region, these are economically viable investments that should be implemented if possible (WS4). **For the reforestation component possible accrual of benefits to private participants was not considered as property rights are uncertain, but the economic CBA again showed this to be a viable and attractive investment from the viewpoint of society.**

These CBAs show that the benefits of SLM that do not directly accrue to the farmer are significant. Most notably, the **net present value contributions of aquifer recharge and carbon sequestration** over 25 years. For Eldamia it is of strategic, environmental, and economic value to ensure that it is in the interest of the farming population to adopt such SLM practices. **Any barriers to adoption such as farm credit constraints, insufficient extension services and land tenure ambiguities should be addressed.** Tree gum production is taxed by trade policy in Eldamia reducing farmers' incentives to plant and care for A. specialis trees. Thus, these CBA results also send a signal to policy makers regarding the effects of such trade policies for an export crop with the potential to expand production to the benefit of both society and the environment. Finally, the CBA of the reforestation component makes a case for reforesting degraded public lands (the barren hills in the Awasha Basin), plus designing effective benefit sharing schemes to incentivise communities to plant, nurture, and care for these areas.

Note, however, that in comparing and interpreting these financial and economic CBA outcomes **not all ecosystem services have been accounted for in economic terms**. This includes some cultural aspects of sustainable land management. Note also that the terracing component is perhaps subject to the most uncertainty of outcome in terms of NPV. This is not least because of its reliance in this analysis solely on the value of increased maize productivity to provide the benefit stream that justifies and recovers the costs of land terracing by farmers.

Finally, it should be noted that per hectare values (as in WS4) cannot simply be extrapolated to larger scales. As noted above, the phasing and costs of project implementation at larger scale must be considered. Also, most ecosystem services are likely to non-linear and place-dependent regarding bio-physical relationships. Thus, for example, doubling the area of agroforestry within the Awasha Basin will not necessarily double net benefits generated. Nevertheless, the per hectare estimates shown in WS3 and WS4 provide a good indication of potential farm level and societal benefits associated with the SLM scenario in Southern State.

7.2 Section summary

This completes Part A) and the Southern State case study from Eldamia. Make sure you understand how the CBAs were constructed using spreadsheets and consider whether you agree with the interpretations of results presented in Sections 6 and 7 above. More information is always useful for decisions. What if any are the main gaps that you see in the analyses covered here? How might you address them in practice? Where would you get the necessary data from? Who can help?

Part B

Northern State case study

ELD steps 1 and 2 Inception and Geographical Characteristics

Section learning outcomes

- Illustration in a brief form of the type of information that would be compiled and assessed in more depth for ELD steps 1 and 2 (information typically gathered within a GIS-based approach and participatory GIS framework).

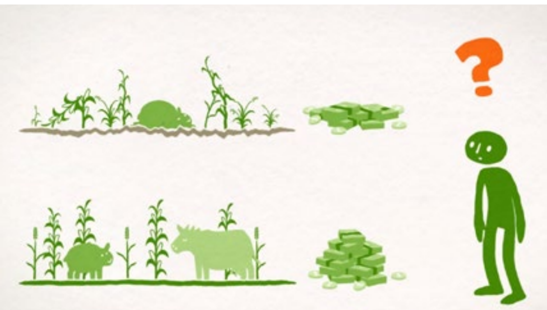
Activity 7: Read Section 8

8.1 Inception: context and aims for the cost-benefit analysis (CBA)

In Northern State, the eastern rangelands are a source of valuable livestock products, carbon storage, biodiversity and medicinal plants (particularly for animal diseases). They also serve as a watershed or basin that receives rainfall, yields surface water, and replenishes groundwater in the coastal strip and areas to the west and south. Appropriate land management to protect and sustain these services for society is generally lacking. Land degradation is resulting in livestock feed deficits, soil erosion, loss of biodiversity and vegetation cover, and expanding desert margins. It is increasingly urgent to implement viable strategies to reverse degradation trends. A possible approach is to re-establish a traditional system of land management that encourages the sustainable, shared use of common resources amongst relevant communities.

FIGURE 3

Need to change unsustainable grazing practices in Eldamia



Changes in the governance of access to land have contributed to the degradation of the eastern rangelands in Northern State. Before the 1940s, pastoralists seasonally migrated across national borders in search of seasonal resources. This allowed forage at each non-grazed site time to regenerate. International security concerns and border restrictions have since disrupted such migration. Tribal land tenure systems have also been replaced by state-ownership of rangelands, with a resulting shift from customary tenure management systems to one of effectively unregulated 'open access'. Livestock owners take advantage of pasture and fodder as available causing over exploitation of edible plant resources and impacts on soil fertility. As rangeland resources declined pastoral communities began to supplement natural forage production with mainly imported concentrated feed. Then, when feed prices rose in the early 2000s government introduced a subsidy for livestock feed. This remains and has encouraged owners to increase herd sizes further worsening rangeland deterioration.

In the local language, *Cala* means 'protected place' and signifies an area that cannot be privately owned and is set aside permanently or seasonally for the collective good. Traditionally, *Cala* areas have been used to conserve natural resources and biodiversity in the eastern rangelands, and it is expected that the revival of *Cala* systems will contribute to their more sustainable use. The approach can be varied to fit local community needs, but with the common element that land is set aside at least seasonally. Restoration of the rangeland depends on rotational grazing protocols that allow 'rested' areas to renew the quality and quantity of forage growth. Resting land allows the natural vegetation to renew energy reserves, rebuild shoot systems and deepen roots, resulting in increased biomass production. This system can also be described as intensively managed rotational grazing or cell grazing. A project to re-establish the *Cala* system will draw on experience from a recent trial conducted by the Ministry of Agriculture (MoA) in Eldamia.

To further test, refine and promote the approach, an ex-ante cost-benefit analysis of a pilot project for rangeland restoration using the *Cala* system is needed. The aim is to determine whether *Cala* system management is better than an open access system in terms of rangeland productivity and economic and financial returns to investments of capital, labour and land resources.

8.2 Geographical characteristics

The study area is within the eastern rangelands in Northern State (Figure 1). The rangelands are bordered by the coast to the north, the national frontier to the east and a watershed to the west and south. They cover an area of 380,000 ha (3800 km^2) and form an important and productive ground water basin. Their geographical position lies between 13.4 to 15.6°N, and 38.4 to 39.8°E.

Areas within the rangelands selected as suitable for *Cala* restoration are those belonging to the state with rainfall levels between 110 and 200 mm. The area selection criteria were defined during an expert workshop. Approximately 109,000 ha were estimated to be suitable for *Cala* restoration, of which areas with the greatest potential in terms of the rainfall gradient are in the southern part of the rangelands.

The geographical boundaries for the appraisal of rangeland restoration using CBA are those defined for a pilot project of 4000 hectares located in the south east of the rangelands. It is assumed that each *Cala* management unit will be 400 ha, further subdivided into cells of 100 ha each as rotating enclosures. The pilot project will thus seek to establish 10 community-managed units.

8.3 Section summary

In Northern State the study area is the eastern rangelands in eastern Eldamia. An economic cost-benefit analysis is needed to compare current and continuing degradation of the rangelands to a scenario in which the rangeland is restored and SLM improvements are achieved.

The SLM scenario to be appraised using cost-benefit analysis consists of rangeland restoration through rotational grazing (or cell grazing) managed under the local *Cala* system.

Types of ecosystem services (ELD step 3)

Section learning outcomes
- Refining the analysis and assessing the type and state of ecosystems services in the study area;
- Use of the MA (2005) ecosystem categorisation.

9.1 Ecosystem services identified

In Northern State the livestock sector relies on healthy rangelands and other sectors also benefit from the ecosystem services that these rangelands produce. Land degradation is resulting in livestock feed deficits, soil erosion, loss of biodiversity and vegetation cover, and expanding desert margins.

Activity 8: Read Section 9 and study WS1 in the Excel workbook for Northern State

Exercise 7: Identify ecosystem services from the eastern rangelands

Before proceeding, review the description of the eastern rangelands given in Sections 1 and 8 above. 'Brainstorm' and write your own list of the ecosystem services which you think are produced in this area. Then categorise your list into provisioning, regulating, supporting and cultural services.
You might want to refer to the module on the identification and selection of ecosystem services within the ELD Campus again.
Answer guideline: when you have drafted and categorised your list compare it to table 3 below.
Do you think we have missed out anything important in table 3?
In practice we should go back to the local stakeholders to discuss and confirm our findings before proceeding with our appraisal of the proposed project.

Table 3 provides a categorised (as MA, 2005) identification of ecosystem service provision in the study area. These services are discussed further below, and data sources for their quantification are outlined.

TABLE 3

Preliminary identification of ecosystem services in Northern State study area

Category	Ecosystem services
A) Provisioning	A1: increased edible biomass on rangelands
	A2: medicinal herbs
B) Regulating	B1: increased infiltration and soil moisture
	B2: infiltration and recharge of shallow aquifer
	B3: reduced downstream sedimentation of reservoirs
C) Supporting	C1: climate change mitigation and adaptation (carbon sequestration)
	C2: conservation of genetic diversity of flora and fauna
D) Cultural	D1: re-established traditional pastoral management system
	D2: sustained pastoralism and livelihoods

9.2 Detail and data sources for ecosystem services and project costs

As you read the details below, see how the data required for the cost-benefit analysis (CBA) has been entered and prepared in the Excel worksheet WS1 for Northern State. Note that three columns are colour shaded and show data for the pre-project situation, the baseline scenario (without project) and SLM scenario (with project).
You can refer to the module on CBA within the ELD Campus again for more basic explanations on the structure of a CBA.

Key point! Note that in WS1 any raw data values are only entered once in building a model of the project that can later be used for sensitivity analysis.

The ecosystem services to be gained or enhanced through the rangeland restoration strategy are considered below. Biophysical models (using high-resolution remote sensing and ArcSWAT) were used to predict how key ecosystem services were affected by change in land management, and a household survey in the MoA Cala trial area was used to collect data on the current practices of livestock owners.

A) Provisioning services

A1: increased edible biomass on rangelands

Rangeland productivity in the eastern rangelands has halved over the last two decades and many indigenous plant species have disappeared. Edible dry matter per hectare decreased from 90 kg/ha in 1998 to 50 kg/ha in 2018 (MoA, 2019).

In the baseline scenario, it is expected that rangeland productivity will continue to decline at a rate consistent with observed trends over the past 20 years (MoA, 2019). Faced with decline in natural forage, livestock herders purchase concentrated feed mainly in the form of barley.

The household survey assessed the purchases of concentrated feed on average each month by livestock owners.

For the SLM scenario, modelling of the rotational grazing of cells in the *Cala* management unit estimated the incremental biomass (per hectare) generated in a *Cala* system compared to an open access regime (baseline scenario). It is assumed that *Cala* management units of 400 hectares will be subdivided into four cells of 100 hectares each and land outside of this will remained open access for grazing. For the first two years grazing will be excluded from three cells. In the third year one cell will be opened for grazing, in the fourth year a second cell while the previous unit becomes closed, and so on with one cell remaining open access in each cycle. In the first two years of *Cala* adoption loss of biomass in aggregate is worsened by the grazing pressure on the open access cell, but from year 3 the situation improves and from years 5 to 17 (over 8 years) rangeland degradation is reversed and significant annual increases in edible dry matter yield are achieved before a relatively steady state of productivity is attained (see predicted data in WS1).

A2: medicinal herbs

Focus groups and key informant interviews conducted in the MoA trial area revealed that livestock owners attribute a premium value to natural forage over concentrated feed. Meat and milk products are considered of superior quality from animals nourished on natural feed due to the higher nutritional and medicinal value of natural forage. Pastoralists also report an increase in livestock diseases previously absent or uncommon when availability of natural forage declines. (See Section 10 below and WS2 for further discussion and valuation approach).

B) Regulating services

B1: increased infiltration and soil moisture

Rehabilitated rangeland vegetation will reduce run-off, enhance water infiltration and soil moisture status, and improve return flows to rivers and streams in dry periods. This has a use-value as herders may be able to use the water for livestock or in supplementary irrigation schemes. It also has an aesthetic or non-use value associated with the appreciation of local people for a more vegetated and less degraded landscape.

B2: infiltration and recharge of shallow aquifer

Annual abstraction of groundwater from the eastern rangelands basin is estimated to exceed 55 million m^3 compared to a safe groundwater yield of about 30 million m^3 per year. The ArcSWAT analysis predicted that on average an additional 4 million m^3 of water would be infiltrated annually to the shallow aquifer as a result of large-scale rangeland restoration (109,000 ha) within the basin. Rangeland restoration over such an area could thus increase the safe yield of the basin by approximately 13% from year 6 following 5 years of rotational grazing and restoration. This would be a significant and beneficial result given the existing high demand for water and excessive abstraction within the basin.

Exercise 8:
Make entry for rate of shallow aquifer recharge in SLM scenario

Using the data already entered in WS1 (Excel file), enter a formula to calculate the shallow aquifer recharge in years 6 to 25 in m^3/ha/year for the SLM scenario (cell E26 in WS1).
Answer guideline: see box at the end of this chapter 9 - after the section summary

B2: reduced downstream sedimentation of reservoirs

Water runoff harvesting is common in eastern Eldamia. Eight small dams have been constructed in the last forty years with a total capacity of around 225 million m^3. They serve for irrigation supply, hydropower, replenishment of aquifers, recreational activities and storage of treated wastewater. However, sediment deposition (much of it originating from barren rangelands) reduces storage capacity, shortens their lifespan and reduces hydropower potential. Rangeland restoration and resulting improved vegetation cover is expected to help stabilize soils and reduce sediment inflows compared to the baseline scenario.

C) Supporting services

C1: climate change mitigation and adaptation (carbon sequestration)

Beneficial impacts in terms of carbon sequestration and storage are expected from rangeland restoration through increased carbon storage in biomass and soil organic matter. Grazing also facilitates the physical breakdown, soil incorporation, and decomposition of residual plant material, and thus grazing intensity and frequency are key determinants of carbon storage across rangelands. In the baseline scenario with continued overgrazing and land degradation, stocks of soil organic carbon (SOC) are predicted to decline by approximately 1% per year, while biomass and above ground carbon (AGC) is conservatively predicted to decline by 0.1% for 15 years and then remain unchanged. In the SLM scenario with rangeland restoration, SOC is predicted to increase by 0.5% per year for 20 years and then by 0.1% per year for five years, and AGC by 3% per year for 15 years and then by 0.5% per year for 10 years.

Exercise 9:
enter data for rates of carbon sequestration in WS1

In WS1 (Excel file for Northern State) fill in the block of cells from A31 to G36. That is enter headings in column A, units in column G and other data as required. Only enter raw data values once and use a formula to link a value to other cells as needed.
Answer guideline: see box at the end of this chapter 9- after the section summary.

C2: conservation of genetic diversity of flora and fauna

Not directly quantified or valued in monetary terms (but at least partly incorporated in estimates for A2 and B1 as described above and in Section 10 below).

D) Cultural

D1: re-established traditional pastoral management system

D2: sustained pastoralism and livelihoods

Both considered intangible, and no attempt made for quantification and valuation beyond the relevant provisioning services considered above.

Project costs (Northern State)

Cost estimates for project implementation were derived from expert interviews and MoA trial area experience. *Cala* restoration has implementation, management and opportunity costs.

Community workshops and expert advice are necessary in the first two years of implementation to raise awareness, gain participation and establish community-based management groups for each Cala unit. The MoA will also incur ongoing annual costs for continued technical advice, supervision and monitoring.

An observation post or tower, donkeys and a motorcycle are needed for surveillance purposes to prevent illegal intrusion of livestock herders.

Each unit will also benefit from equipment purchased to process dried medicinal plants collected in the *Cala* sites.

Community management costs, including daytime surveillance activities, are considered equivalent to existing and baseline scenario household own-labour use for grazing management. But illegal intrusion to a *Cala* site often happens during the night and it is therefore necessary to remunerate labour for night-time surveillance. These costs will be higher for the first two years as herders from other communities will need to learn to respect boundaries that do not exist at present. The household survey revealed, for example, that some herders travel up to two hours by truck with their sheep and goats at night to reach green pastures.

Technical expertise is also needed to conduct vegetation biomass studies and establish the animal carrying capacity of each *Cala* site, as this depends on a complex set of variable climatic and agroecological conditions. This cost is incurred for the first 5 years after which it is assumed that capacity will be built in the community to manage stocking rates.

Although based on expert opinion and existing evidence, all cost estimates are subject to uncertainty. However, the values used are expected to be an upper estimate of actual restoration costs. The expansion of *Cala* restoration from initial sites is likely to be associated with economies of scale, for example related to the informal transfer of knowledge between communities, the re-establishment of known traditional practices, capacity building for community-based management and the evolution of other peer to peer self-enforcement mechanisms.

9.3 Section summary

In this section ecosystem services for the Northern State study area have been identified and categorised. Data sources and quantitative descriptive data have also been summarised. The relevant data is shown in WS1 in the Excel file, where it has been entered as the first stage in building up a cost benefit analysis.

Consider the changes and trends predicted for different variables for the baseline (without project) and SLM (with project) scenarios. How would you best present these in a spreadsheet to compare incremental costs and benefits arising in the project and determination the incremental net benefit stream.

Again, it is important to understand which benefits and costs have been identified and quantified (if not yet all valued) for the rangeland restoration project. Also, to recognise and take note of benefits or costs which may not have been quantified so far because of a lack of data or for other reasons. Such omissions should be kept in mind when the results of the CBA are interpreted below.

Solutions to the exercises in this chapter:

Exercise 8:

Answer guideline: the calculated value shown in your worksheet should be cell E26 – 89 m^3/ha/year

Exercise 9:

Data for rates of carbon sequestration (SOC and AGC)

Answer guideline: your completion of WS1 should look like this:

	A	B	C	D	E	F	G
30	Carbon sequestration						
31	soil organic carbon (SOC), year 1		6	6	6		tonnes/ha/year
32	annual change in SOC, years 2 to 20			-1%	0.5%		%
33	annual change in SOC, years 21 to 25			-1%	0.1%		%
34	above ground carbon (AGC), year 1		0.5	0.5	0.5		tonnes/ha/year
35	annual change in AGC, years 2 to 15			-0.01%	3%		%
36	annual change in AGC, years 16 to 25			-0.01%	0.5%		%

CHAPTER

10

ELD step 4 Role of ecosystem services and economic valuation

Activity 9: Read Section 10 and study WS2 in the Excel workbook for Northern State.
Also read the following box as you progress through this section:
CBA explanation: stated preference methods and choice experiments.
You can also refer to the module on valuation methods within the ELD Campus.

Section learning outcomes

- Illustrations of the role of identified ecosystems services in livelihoods and economic development;
- Practice in working with estimates of economic value of these services;
- Illustrations of how these estimates seek to apply the concept of total economic value (TEV);
- Appreciation of sources of bias, inaccuracy and uncertainty in non-market economic values.

10.1 Ecosystem services valued, and valuation methods used

Table 4 summarizes the benefits (ecosystem services) valued for the study area and the valuation method that was used. Valuations and data sources are discussed further below.

10.2 Detail and data sources for economic valuation

As you read the details below, see how the data required for the cost-benefit analysis (CBA) has been entered and prepared in the Excel worksheet WS2 for Northern State and how it relates to data in WS1. Note that three columns are again colour shaded and show data for the pre-project situation, the baseline scenario and SLM scenario.

TABLE 4

Ecosystem goods and services valued for Northern State study area and the valuation approach used

Category	Ecosystem services	Biophysical impact	Valuation approach
A) Provisioning	A1: increased edible biomass on rangelands	increased natural forage available	replacement cost of livestock feed purchases
	A2: medicinal herbs	improved animal nutrition and reduced animal disease	stated preference choice experiment
B) Regulating	B1: increased infiltration and soil moisture	extended grazing areas and periods, enhanced stream flows and landscape value	
	B2: infiltration and recharge of shallow aquifer	increase in available groundwater	replacement cost of trucked water for livestock
	B3: reduced downstream sedimentation of reservoirs	sustained reservoir storage capacity	replacement cost of water storage capacity lost
C) Supporting	C1: climate change mitigation and adaptation (carbon sequestration)	CO^2 sequestered	avoided damage cost, using the social cost of carbon

Ecosystem services identified in Section 9 for Northern State have been valued as follows:

A) Provisioning services

A1: increased edible biomass on rangelands

Given the household survey data that livestock owners purchase a high proportion of feed (75%), any marginal increase in rangeland forage production will directly substitute for the need to purchase feed. The value of increased rangeland biomass may therefore be estimated as the replacement costs associated with feed purchase that will be avoided.

Natural forage grazed is converted into feed barley equivalents to estimate the replacement cost associated with feed purchase (each tonne of edible dry matter from rangelands is equivalent to an amount of barley in terms of nutritional value).

Most barley used in Eldamia is imported since domestic barley production is negligible. Sheep and goat herders can purchase imported barley at a domestic price subsidised by government. For the project level economic analysis, the world market price at which the government imports feedstock was used to derive an estimate of economic value to Eldamia of avoided feed purchase.

Coarse grain barley feed prices are predicted to rise in real terms relative to the general price level in line with world agricultural commodity price forecasts and rising global demand compared to supply. Consequently, the additional natural forage from rangeland restoration will become more valuable over time because the relative feed prices are increasing.

Key point! Note this exception to the use of constant prices for other costs and benefits in this analysis (the social cost of carbon is also such an exception as considered below).

A2: medicinal herbs

Natural forage is considered to have superior nutritional value and it contains plant species that have medicinal value and are associated with reduced incidence of some livestock diseases. Valuation has been made jointly with ecosystem service B1 as explained below.

B) Regulating services

B1: increased infiltration and soil moisture

Rehabilitated rangeland vegetation reduces runoff, enhances water infiltration and improves return flows to rivers and streams.

The benefits of natural forage (A2) and enhanced infiltration and soil moisture (B1) could not be valued using market prices for products or replacement costs. Hence, a stated preference choice experiment (CE) was implemented to assess the economic values associated with rangeland restoration, natural forage and enhanced soil moisture and stream flows.

CBA explanation: Stated preference methods and choice experiments

Environmental valuation assumes that individuals' preferences (what people want) should be the main guide to determining values and hence to accounting for costs and benefits and making investment and resource allocation decisions. Economists assume value is determined by individual preferences as measured in monetary terms. Adding everyone's willingness to pay (WTP) to gain an environmental benefit (or avoid its loss) produces the overall or aggregate WTP for a gain or loss to society.

Competitively determined market prices can be assumed to measure WTP for the consumption of goods and services, but an individual often benefits from an environmental good or service without paying for it as there is no market. If so, the price that an individual would be willing to pay must be derived from survey data, or other means (e.g. a proxy method such as the replacement costs or avoided damage costs used for other ecosystem services in these case studies).

Stated preference valuation methods use questionnaires and surveys to value WTP by analysing an individual's preferences for environmental goods. The leading stated preference methods are contingent valuation surveys and choice experiments (also known as choice modelling).

Choice experiments use surveys in which respondents are offered a series of 'choice sets' consisting of three or more options or attributes, one of which is usually 'no-change' or 'do nothing' and one a financial impact (value). Respondents choose their preferred option from each choice set and from a sample of responses analysis can estimate the relative importance of each attribute. The inclusion of monetary and non-monetary attributes enables estimation of the value of the non-monetary attributes such as an ecosystem service.

Source: Smith 2019

In the CE respondents were asked to choose between three landscape scenarios: a continuation of the present landscape and two future restoration scenarios. Each future restoration scenario was associated with a monthly cost additional to that which the livestock owners currently pay for purchased feed. Respondents could choose the current situation if they thought either of the future scenarios was too expensive to pay for. Visual aids were used to depict changes in landscape and forage availability.

B2: infiltration and recharge of shallow aquifer

ArcSWAT analysis predicts a significant change in the level of aquifer recharge after five years of Cala restoration. To estimate the economic value of the additional ground water, interviews elicited how much herders are willing to pay for water that is trucked in for their livestock. Livestock owners surveyed were willing to pay no more than 20 ES/m3 of water on average.

B3: reduced downstream sedimentation of reservoirs

This ecosystem service has economic value in maintaining reservoirs for economic activities and has been valued through the replacement cost approach. Demand for water will increase in Eldamia and it can be assumed that any storage capacity in reservoirs lost through sedimentation will need to be replaced on an annual basis. For the SLM scenario, avoided reservoir replacement costs from rangeland restoration were estimated using ArcSWAT to forecast annual sediment loadings for the baseline and SLM scenarios, conversion of annual change in sediment loading to volume (using the average bulk density for soil in the area) and estimates of the annual cost of constructing additional water storage capacity. The average cost of building additional storage capacity was taken from the recently estimated costs of expansion of the largest reservoir in the region by heightening its dam. It was assumed that it will take 5 years for the full soil retention capability of Cala management units to be established.

C) Supporting services

C1: climate change mitigation and adaptation (carbon sequestration)

Given the predicted biophysical relationships in each scenario described above, the economic benefits of carbon sequestration are valued using avoided social cost of carbon (SCC) estimates. Enhanced carbon storage is valued as the damage costs of climate change impacts that would be avoided by reducing carbon dioxide emissions each year. These damages include decreased agricultural productivity, impacts of rising sea levels and harms to human health. Social cost of carbon (SCC) estimates reported by the US EPA are used for this. SCC values are estimates of the damage associated with climate change impacts that would be avoided by reducing carbon dioxide (CO_2) emissions by one metric ton in a given year. SCC estimates are assumed to increase over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change.

Non-valued benefits and costs for the Northern State study:

The benefits derived from increased biodiversity of edible biomass were valued using the choice experiment as described above, but other forms of biodiversity improvement such as return or increase in number and diversity of invertebrates, mammals and birds that depend on healthy rangelands were not because of a lack of data for this.

However, it is known that there should be a positive impact for such biodiversity, with related potential spinoffs for hunting and ecotourism, and the total benefits estimates of rangeland restoration in the area are thus underestimated in this respect.

Cultural services/impacts have not been valued.

10.3 Section summary

In this section ecosystem services for the Northern State study area have been valued, usually per hectare or per 400-hectare Cala management unit, and per year. Data sources and relevant data have been summarised in this section. The relevant data is shown in WS1 and WS2 in the Excel file for Northern State.

In preparation for the CBA, the biophysical changes identified from biophysical models were translated into economic values of key ecosystem services using a combination of market prices, replacement costs, stated preference and avoided costs valuation approaches.

Using these approaches, the value of Cala rangeland restoration was estimated in terms of increased edible biomass, valued in terms of the concentrated feed which it replaces, the premium associated with natural forage over concentrated feed, the extent of water infiltration resulting from biomass and the value of that water, the value of reduced sedimentation of dams in terms of increased storage capacity and the value of increased carbon sequestration.

Key point! Note that for these ecosystem services and their value, different trends and rates of change have been predicted for both the baseline scenario (usually declining/worsening trends) and the SLM scenario. This contrasts to the Southern State study for which the baseline scenario assumed no change in prevailing conditions for the without project scenario from the start of the project.

Again, it is important to recognise and take note of benefits or costs which have not been quantified and valued so far because of a lack of data or for other reasons. Such omissions should be kept in mind when the results of the CBA are interpreted below.

ELD step 5 Land degradation patterns and pressures and scenarios

Activity 10: Read Section 11

Section learning outcomes
- Identification of land degradation patterns, and drivers and pressures affecting the sustainable management of land resources
- Alternative scenarios for cost-benefit analyses
- Iterative review and revision of previous steps as needed.

Section 8.1 above described land degradation patterns and pressures.

As you read this section start to consider how the data and calculations for the cost-benefit analysis (CBA) can be best entered and presented in Excel worksheets.
You might want to refer to the modules on the ELD steps and on CBA within the ELD Campus again for explanations on CBA, scenarios, etc.

11.1 Valuation scenarios to be analysed

Northern State:
Baseline scenario: 'business-as-usual' consisting of a continuing trend in land degradation

↓ ↓ ↓

Future scenario: investment made, and reduced land degradation and improved ecosystem service provision achieved.

The baseline scenario assumes that there will be no reduction in livestock numbers and a downward trend in the level of precipitation. Thus, there will be continued declines in rangeland productivity, at least at the rate that has been observed over the last 20 years. This corresponds to a continuing decrease in biomass and edible dry matter per hectare per year, high run-off during rain events, high levels of soil erosion and low infiltration with poor groundwater and river recharge. Carbon sequestration rates are also predicted to decline in line with decreasing biomass.

The future scenario assumes that the *Cala* system of rangeland restoration is implemented in the selected areas leading to enhanced provision of ecosystem services. It is assumed that the principles, lessons and general management regime of the MoA trial can be applied in all areas considered suitable for the *Cala* system within the eastern rangelands in terms of allowed stocking density, allowed grazing periods, and spatial arrangement of grazing allowances.

For the trial, *Cala* management units of 400 hectares were sub-divided into four cells of approximately 100 hectares each, and land outside of these cells remained open access (i.e. open to grazing by any ownership, number of livestock and length of time). During the first two years of the system being established, grazing was altogether excluded from three cells. In the third year, one of the cells was opened for grazing. In the fourth year, a second cell was opened for grazing, while the previous cell was closed, and so on. This rotation is then continued thereafter assuming the system can be protected from unscheduled grazing by outsiders. One cell thus remains open access in each cycle. This allows for more flexibility in grazing management and reflects how *Cala* systems usually worked in the past by ensuring that there is always a space where ruminants can graze when the other cells are restricted. This does increase grazing pressure in the open access cell and this implicit 'displacement' cost was incorporated in the biophysical modelling.

Stocking rates and allowed grazing times are predetermined for each year. Grazing is only allowed during the autumn months to ensure regeneration of biomass cover, and indicators of edible biomass are used each year to establish allowed stocking density and grazing period and duration. Allowable grazing periods can be expected to lengthen over time as biomass and soil moisture status are re-established and increase. More sophisticated herding arrangements could evolve as *Cala* use becomes more widespread, further improving fodder availability and reducing the need for open-access grazing zones. However, this study is restricted to the implementation and potential scaling-up of *Cala* as envisaged above.

11.2 Section summary

Information in this section is limited for this fictional case compared to that which would be provided in an actual case study. Pastoral systems can be complex in their operation and management, and rangeland restoration is challenging. Livestock numbers may be unlikely to remain constant in the SLM scenario. In an actual situation what further information would you seek to assist your planning and appraisal of rangeland restoration scenarios?

CHAPTER

12

ELD step 6 Cost-benefit analysis (CBA) and decision-making

Activity 11: Read Section 12

Section learning outcomes

- use of CBA to appraise a sustainable land management project
- practice in completing a CBA for a rangeland restoration project
- further understanding of how use of CBA can help assess options for the location, scale of intervention, alternative technologies and implementation approaches
- further understanding of how to treat risk and uncertainty.

This section is divided into the following steps in completion of a CBA:

1. Definition of the timeframe for analysis, identification and categorisation of benefits and costs (from steps 3 and 4 above) and choice of discount rate.
2. Calculating an annual incremental net benefit stream under alternative scenarios.
3. Deriving measures of project worth, i.e. economic indicators of whether an investment is worth undertaking (including net present value, internal rate of return, and benefit-cost ratio).
4. Undertaking a sensitivity analysis to assess impacts of uncertainty.

You might want to refer to the module on CBA within the ELD Campus for explanations and guidance on the economic terms.

12.1 Timeframe for CBA and discount rate

For this project appraisal in Northern State a project life of 25 years has been adopted. This is enough to allow full development of the benefits expected from rangeland restoration compared to the predicted continuation of land degradation in the baseline scenario.

For financial analysis the discount rate is 8%, and for economic analysis 5%.

Benchmark interest rates for Eldamia have fluctuated between 5 and 6% over the last five years (the minimum rate of return investors will accept for buying non-government securities). For financial farm level analysis a discount rate of 8% was used to reflect that some investors will demand a higher rate of return for investment in projects subject to natural risks.

Private discount rates are generally considered to be an upper bound for public projects in Eldamia because rates of return to public sector investments are usually lower than for the private sector. A discount rate of 5% was thus used for economic analysis (this is also in accord with recently issued US guaranteed Eurobonds, frequently leveraged to finance government spending in Eldamia).

Benefits and costs for the projects were identified and categorised in Section 9 above, and information for their valuation compiled in Section 10.

12.2 Calculating an annual incremental net benefit stream under alternative scenarios

Northern State

Please refer to WS3 in the Excel file for Northern State

Financial analysis is first conducted at the community level for a typical Cala management unit. The objective is to assess the financial viability of the SLM interventions at community level.

Note that the tables in WS3 effectively consist of a series of partial budgets that compare changes in benefits and costs in each year for the baseline and SLM scenarios. Assuming other costs and beneficial outputs remain unchanged from the viewpoint of the community managing the *Cala* unit, differing trends in availability of natural forage and need to purchase concentrated feed are evaluated. There are trends in both rangeland edible dry matter yield and the relative price of concentrated feed to be accounted for. For ease of calculation and clarity of presentation, trends in rangeland edible dry matter and quantity of concentrated feed purchased are first shown (rows 6 and 7, and rows 17 and 18 in Worksheet 3), before conversion to values.

Key point! WS3 consists of community level analysis and data is calculated and presented for a Cala management unit of 400ha. Layout and data presentation are a choice for the analyst, but coherence and logic must be maintained.

From the choice experiment, WTP values for improved animal nutrition and increased availability of medicinal herbs, plus for increased infiltration and stream flows, have been included as financial benefits for the community. It is perhaps debateable whether such values should be included here as they are not derived from market transactions, but they do represent ecosystem services which livestock owners are willing to pay for in order to gain benefits in terms of the enhanced provisioning services of livestock products (or cost savings) which are produced. That is, the herders expect to gain actual financial benefits from the ecosystem services in terms of reduced veterinary costs, improved nutrition of their animals and increased access to water in streams and shallow wells.

Benefits accruing to the community from introduction of the *Cala* system are set against the incremental costs of setting up and managing the *Cala* unit.

The net benefit in the baseline scenario is then deducted from the net benefit in the SLM scenario to provide the annual incremental net benefit stream (row 39). This achieves the 'with' v 'without' project comparison year by year allowing for predicted annual changes in both baseline and SLM scenarios.

Key point! The opportunity costs of restoration, namely the known forgone benefits of continuing grazing, are already incorporated in this cost benefit analysis, since the scenarios are compared assuming number, productivity and value of livestock and their production is the same in each whilst incremental feed cost saved and other incremental benefits of restored rangeland are compared (see WS3).

However, the viability of the Cala system to a community is probably underestimated here. The carrying capacity of the rangeland is predicted to effectively decline to zero over 25 years in the baseline scenario. To maintain current production livestock would have to become enclosed and entirely fed on concentrated feed. This may be unsustainable even without consideration of the overall degradation of the landscape and its ecosystem services, and at minimum would incur additional costs for animal enclosure, labour and waste disposal.

Using a lengthy formula, row 48 recalculates the incremental net benefit stream by valuing feed barley at the import parity price rather than at the subsidised price paid by farmers. This is so that the recalculated values can be used in the economic analysis in WS4 as discussed further below.

(The formula in each cell in row 48 is lengthy but arithmetically simple. The value for each element calculated using the subsidised price is first removed and then added back calculated using the import parity price. Signs for + and – are used as needed for costs and benefits to maintain the with v without project comparison).

Exercise 10: Building benefit and cost streams at community level

Answer guidelines: see box at the end of this chapter 12, after the section summary

a) Using the data already entered in WS1 and WS2 (Excel file), enter formulae in WS3 to calculate the Rangeland edible dry matter (EDM) yield value (row 17) and purchased coarse gain barley feed cost (row 18) for each year for the SLM scenario.

b) Enter formulae in WS3 to calculate the three rows of benefits in the SLM scenario (rows 21, 22 and 23).
Row 21 is the Value of EDM as feed barley equivalent. The calculation is similar to row 10 for the baseline scenario, i.e. EDM yield x feed barley equivalent ration x Cala management unit area x barley feed price to herders
Row 22 is the annual value of WTP for feed to be natural forage + herbs (Check which value applies in each year and multiply monthly value from WS2 for a year).
Row 23 is the annual value of WTP for water return in dry streams.

c) Enter formulae in WS3 to add the data for each year for the SLM scenario for the recurrent management costs of the Cala system (rows 33, 34 and 35). Use the cell references to transfer the data correctly into WS3 from WS1.

Study the incremental net benefit stream (row 39 in WS3). Do you think this is attractive to the community managing the Cala unit provides them with incentive to participate in the project? What about the outcomes in terms of NPV, IRR and BCR?

We will return to these questions below.

Please refer to WS4 in the Excel file

Economic analysis is conducted at the project level in WS4. The chosen scale is for a pilot project to be implemented by MoA in Eldamia, consisting of 10 Cala management units making up an area of 4000 hectares.

Key point! WS 4 consists of project level analysis. Values are shown for the pilot project of 4000 hectares. This is a choice by the analyst, but again coherence and logic must be maintained.

As this is project level analysis and from the economic or societal viewpoint, additional benefits and costs to those considered at community level are included as necessary. This includes the benefits of enhanced carbon sequestration with rangeland restoration in the SLM scenario. But, because carbon sequestration is predicted to decline in the baseline scenario, WS4 first shows this trend in the value of carbon sequestration. The values calculated in rows 5 and 6 take account of both the annual rate of decline in SOC and AGC, and the increasing value of the SCC.

Also note that row 11 takes community level incremental net benefit from WS3 (from row 48) scaled up for the pilot project area. Together with the value of carbon sequestration, this takes account of the baseline scenario (i.e. the without project situation). The additional benefits from enhanced ecosystem services that benefit society as a whole and not just the livestock owners are then included in rows 12 to 15 (including enhanced carbon sequestration). And project level incremental costs for implementation are set against these in rows 18 and 19.

12.3 Deriving measures of project worth

Please refer to WS3 and WS4 in the Excel file for Northern State

Calculating NPV, IRR and BCR

Exercise 11:
Calculating measures of project worth for rangeland restoration

Enter formulae in WS4 to calculate the NPV, IRR and BCR for the project of 10 *Cala* units (cells C24, C25 and C29). If you are not familiar with the formulae needed see the other examples already calculated in WS3 and the guide immediately below.

Excel formulae:

for NPV, enter:
=NPV (cell containing discount rate, range of cells for incremental net benefit stream)

for IRR, enter:
=IRR (range of cells for incremental net benefit stream, cell containing discount rate)

for BCR, enter:
NPV for incremental benefits / NPV for incremental costs

How do you interpret the NPV, IRR and BCR values calculated in WS4?

We will return to this below.

Interpreting NPV, IRR and BCR values

Please refer to WS3

At the community level, the positive NPV value, IRR marginally greater than the relevant discount rate (8%) and BCR value marginally greater than one all indicate that the investment in the *Cala* system by livestock owners is financially viable. In other words, the costs of adoption and management are outweighed over 25 years by the benefits of more and better natural forage, reduced purchase of concentrated feed and increased infiltration of rainwater in soils and for stream flows.

At face value this should provide incentive for herders to make this change in their pastoral system, although it is a marginal investment valued in financial terms, with viability dependent on the values for WTP entered from the choice experiment. The analyst should also inspect the pattern of the incremental net benefit stream (row 39). The herders sharing the *Cala* area of 400 hectares will be worse off in the first seven years compared to the baseline scenario. Can they rely on their own savings to meet this gap? Can they reduce their household consumption? Will there need to be credit provision to enable them to make this investment? Overall, are incentives enough given the need to work together, including the need for surveillance and exclusion of outsiders (and risks of not achieving this)?

From row 48, the incremental net benefit stream valuing feed barley at the import parity price, achieves a higher NPV and IRR compared to use of the subsidised price because of the higher value of enhanced natural forage over time valued as feed barley equivalent. However, negative incremental benefit is even higher for the community in the first four years (compare rows 39 and 48), though it improves comparatively in years 5 and 6, and becomes positive from year 7 onwards.

What would you recommend to government concerning the subsidy for imported barley feed?

Thus, the outcomes of the CBA provide information but not all the answers. The information should inform decisions on whether and how to proceed but choices must still be made. Stakeholder input into project design and implementation will be essential.

What is your interpretation of the outcomes? Are short and long-term incentives enough for herders to participate and work together? Will assistance in the form of a credit scheme be needed? And what other factors may influence the decisions made by the community and by government?

Please refer to WS4

Consider the NPV, IRR and BCR values for the project level analysis.

From the viewpoint of society, the pilot project of 10 Cala units is a viable investment that can be selected for implementation if the necessary funds are available. Further expansion of the Cala system could also be planned at the scale deemed feasible and affordable.

12.4 Undertaking a sensitivity analysis to assess impacts of uncertainty

Exercise 12: Sensitivity analysis for rangeland restoration

Answer guidelines are given at the end of this chapter, after the section summary.

a) Explore the effect of increasing and decreasing the barley feed subsidy to herders (as a percentage of the import parity price; cell B8 in WS2).
Restore original value; i.e. 40%.

b) What is the switching value for the cost of labour for night-time surveillance in years 3 to 25 inclusive? Change value in cell E47 in WS1.

Key tip! To find switching values try out the 'Goal seek' function in Excel. Depending on your version of the software and add-ins you may find this under the 'Data tab' and 'What-if analysis'. It allows you to name the cell containing the NPV calculation to be set to zero by change in the value of another chosen cell.

Restore original value.

c) What is effect of setting the cost of trucked water, the cost of reservoir storage capacity and the social cost of carbon (SCC) to zero in all years in the SLM scenario? (Changes in WS2).
Restore original values.

d) What is the switching value for the cost of community workshops, awareness raising and expert advice in years 1 and 2 (Cell E51 in WS1).
Restore original value.

12.5 Section summary

Section 6 has taken you through the main steps of cost benefit analysis for a SLM project for rangeland restoration in Northern State in Eldamia.

It should have reinforced your learning on how to layout a CBA using a spreadsheet and how to analyse a project from different viewpoints. In this case, the community viewpoint (private) and society's viewpoint (economic).

In this example, some more complex evaluation of increasing and decreasing trends over time in key variables for both the baseline and SLM scenarios was necessary.

Solutions to the exercises in this chapter:

Exercise 10

a) Answer guideline: Sample calculated values shown in your worksheet should be:
cells C17 – 42; C18 – 158; AA17 – 199; AA18 – 1.

b) Sample answer guideline: cell H21 – 23742; AA21 - 122910
cell H22 - 7440; AA22 - 14400
cell H23 - 6120; AA23 - 6120

Exercise 11

Answer guideline: the calculated values shown in your worksheet should be:
cell C24 – 40,481,329
cell C25 - 22%
cell C29 – 14

Exercise 12

Answer guidelines:

a) Perhaps counterintuitively, increasing the percentage subsidy reduces the NPV at the community level (WS3). This is because it reduces the value of increased natural forage production valued as barley feed equivalent (the main benefit to the community of rangeland restoration). There is no change at the project level (WS4) as here the import parity price is used to value barley feed. The subsidy is a transfer payment from government to herders and is not counted in the economic analysis.

b) The switching value is 61985 ES/400ha/year. A value only price 3% higher than the best estimate for the analysis. Such an increase is very possible, and effective surveillance is critical for the success of the rangeland management system.

c) At project level (WS4) the outcome is still a positive NPV and IRR of 10%. Disregarding the other ecosystem services the benefits of rangeland restoration in terms of increased production of natural forage alone are sufficient to cover the investment and operating costs of the proposed rangeland restoration system. This contrasts with the marginal financial outcome at the community level.

d) Switching value for this investment cost at project level is over 2 million ES/400ha/year, an unlikely figure much higher than the budgeted value of 100,000 Es/400ha/year.

CHAPTER

13

Take action: Policy making and adoption of practices (ELD step 6+1)

Activity 12: Read Section 13

Section learning outcomes

- Further illustration of how the results from CBA can raise awareness and influence policy and investment decision-making.

13.1 How CBA results can inform action

The final step in the ELD approach is the implementation of the most economically desirable options by private actors and public decision-makers. The outcomes of this CBA are thus important to livestock owners, rural communities and policymakers (society as a whole).

The study has shown that large-scale adoption of the Cala approach to enable pastures to be grazed and rested systematically within the eastern rangelands may deliver significant and long-term benefits to Eldamian society. Results show that even without counting for carbon sequestration, sediment stabilisation or aquifer recharge, it is in the long-term interest of rangeland communities to use the *Cala* system to manage their rangelands, as long as they are prepared to make the initial investment and provided they have a reliable tenure system and rights. The system requires clarity over rights of access and management of rangeland resources; for example, the ability to exclude grazing during designated periods of resting the land.

Whilst some benefits of improved rangeland management will be directly captured by livestock owners, and in this analysis do just provide a financial incentive over time to adopt the *Cala* system, options could be explored to provide further incentive by compensating pastoral communities for other benefits that accrue to wider society (and even globally). Such benefits include, for example, enhanced carbon sequestration. Options to consider could include the possibility to sell 'emission reductions' under an emission trading or voluntary carbon offsetting scheme.

Other regulating services provided by rehabilitated rangelands benefit the eastern region of the country. For example, less sediment per annum deposited in reservoirs will help safeguard provision of hydroelectric power and water supplies to urban areas. Similarly, enhanced ground water infiltration will help sustain safe yield abstraction rates within the eastern rangelands basin. Rangeland restoration through the Cala approach may be a cost-effective way of responding to increasing demand for water, and a case can be made for establishing payments for ecosystem service schemes. For example, public water utilities could use revenue collected from urban water consumers to compensate pastoralists upstream for reduced soil erosion and enhanced infiltration.

The case for action to achieve more sustainable land management is further reinforced by the fact that a continuing trend of land degradation is predicted for the 'business as usual' (without project) scenario. The numbers of livestock currently owned in the eastern rangelands depend upon high levels of concentrated feed imports at a significant cost to government finances for the subsidy provided. Without action the availability of natural forage will further decline and feed imports and the cost of their subsidy will increase, or alternatively livestock numbers and their production must decline.

This analysis also shows that appraised over 25 years one Cala management unit could achieve a higher NPV when imported barley feed is purchased by herders at the import parity price rather than the subsidised price. This suggests further policy options. For example, to help finance and incentivise rangeland restoration by pastoralist communities, their receipt of the feed subsidy could initially be made conditional on improved rangeland management and then phased out (after say four years) to further incentivize substitution of natural forage for imported feed.

This appraisal was conducted based on a relatively simple form of rangeland management, using well defined periodic exclusion of grazing to rest pasture on a small scale, and with the assumption that livestock numbers and production remain unchanged. Other management strategies could be researched and appraised in more detail. Thus, whilst this appraisal shows that rangeland restoration is cost effective and economically viable, the study may also underestimate the true potential for rangeland rehabilitation. Cultural ecosystem services have not been valued, nor the potential value of enhanced biodiversity for ecotourism or possibly sport shooting. But, on the other hand, care must be taken in implementation to ensure restored rangeland does not encourage an unsustainable increase in livestock numbers and a renewed cycle of overgrazing and land degradation that would reduce predicted benefits.

13.2 Final summary

By working through this module, you have been able to review and complete two case study CBAs for sustainable land management project. These provided contrasting examples in terms of farming systems, land cover and use types and scenarios. It is hoped that they have successfully illustrated both strengths and advantages of use of CBA in this context, as well as limitations.

The cases have illustrated that a major strength of CBA is that used with appropriate interpretation of data quality and uncertainty it can generate many insights to inform both policy decisions and project design choices. It can help avoid poor investment choices and poor project designs. It can provide insights on how to develop enabling and supportive policies for efficient and sustainable use of natural resources and ecosystem services.

For the Southern State case study this was illustrated by the potential benefits of agroforestry and reforestation at large scale. Also, the benefits of conservation of soil and water through terracing of cultivated slopes. For the SLM interventions analysed, private and social outcomes coincide as both being net beneficial and suggest that the technologies and land management practices involved should be promoted for adoption as much as possible. In terms of policy, the CBA also indicates that trade policies could be revised to further incentivise production of an export tree crop which can benefit farmers, economic development and the environment

The Northern State case study dealt with some of the complexities and challenges of rangeland restoration. Given the data and assumptions used, it revealed some contrast in outcomes between the marginal incentives and private benefits for pastoralists and the much greater wider economic benefits for society. In policy terms this makes the case for finding ways to support pastoralists in their adoption of improved rangeland management systems and some possible policy options for this were identified above.

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This document was published with the support of the European Union and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

Photography: Front and back cover © GIZ
Design: kippconcept GmbH, Bonn
Bonn, September 2019

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