MODULE 5

NATURAL RESOURCE ECONOMICS AND SCARCITY

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5.1 BIOPHYSICAL CHARACTERISTICS OF NATURAL RESOURCES

As illustrated in module 3, natural resources play a central role in the economic development of eastern and southern African countries. The two broad categories of natural resources are “renewable” and non-renewable”. **Renewable resources** naturally regenerate within a reasonable time. Renewable resources include forests, fish, wildlife, water, agricultural crops and even soil. Stocks are not fixed but can be increased or decreased. A given stock of renewable resources such as a natural forest, will grow at a certain rate depending on factors such as weather, average age of the stands, soil nutrients, etc. The forest stock generates a flow of outputs, in this case timber and non-timber products as well as ecological services such as erosion control and oxygen recycling. The stock level largely determines the sustainable flow of outputs. At the same time however, natural losses from fire, insects and disease, etc. will occur. Depending on the interaction of natural growth and losses, the total stock volume may be maintained at a constant level, increased, or decreased.

A basic biological concept of renewable natural resource management is that of sustained yield, where the average rate of depletion is maintained at the rate of average net stock growth. Sustained yield has been defined by foresters as managing a forest for continuous production to achieve a balance between net growth and harvest (Davis 1966). In theory, this results in the forest stock level being maintained in perpetuity[1]. The potential to augment the renewable stocks through human intervention is often quite high (Tietenberg 2000). Excessive fishing or forest harvesting beyond the average rate of stock growth will deplete the stock, thereby reducing sustainable flow of outputs. Recycling some products such as paper will reduce the pressure to harvest natural forests. Establishing sustainably managed forest plantations will also reduce the pressure on natural forests. Using more efficient milling technology will result in less raw timber being required for the same level of lumber production. Storing renewable resource products can also smooth out the cyclical demands for raw materials such as fish and forests. Unfortunately, where human resource demands plus natural losses (fire, insects, disease) exceed the sustainable harvest, then the stock will

[1] This concept is explored in more detail later in this module. A simple analogy is to assume the stock level is a lump sum of cash deposited into a bank at a certain annual interest rate. The annual interest earnings are equivalent to the flow of benefits. Increase the stock and you can increase the sustainable flow of income. If you begin to cut into the capital stock, your sustainable interest earnings (flow) must decrease. If your “harvesting” includes both interest (sustainable flow) and part of the capital stock, your stock volume will gradually decline. Keep going at this rate and you will totally deplete your capital stock!

be reduced. In eastern Canada during the 1980s, massive forest "harvesting" from an epidemic of defoliating insects (spruce budworm), meant that industry harvesting levels were constrained for several years to prevent the total harvest by insects and humans exceeding the sustainable yield.

Non-renewable (or depletable) resources have such a long period of natural regeneration that the potential to augment stocks though human intervention is virtually zero. Stocks are essentially fixed. Common examples are minerals and petroleum where millions of years are required for stocks to naturally form in the earth's crust. Non-renewable natural resource stocks can be classified into several categories (Figure 5.1). Definitions are provided in Box 5.1.

Figure 5.1: Non-renewable natural resource stock classification

Total Resource Stock					
	Identified			Undiscovered	
	Demonstrated		Inferred	Hypothetical	Speculative
	Measured	Indicated			
Economic	Current Reserves				
Sub-economic					

Source: Tietenberg (2000).

Box 5.1: Non-renewable stock definitions

Identified resources: specific bodies of mineral-bearing material whose location, quality and quantity are known from geological evidence, supported by engineering measurements.

- **Measured resources**: material for which quantity and quality estimates are within a margin of error of less than 20 percent, from geologically known sample sites.
- **Indicated resources**: material which quantity and quality have been estimated partly from sample analyses and partly from reasonable geological projections.
- **Inferred resources**: material in unexplored extensions of demonstrated resources based on geological projections.

Undiscovered resources: unspecified bodies of mineral-bearing material surmised to exist on the basis of broad geological knowledge and theory.

- **Hypothetical resources**: undiscovered materials reasonably expected to exist in a known mining district under known geological conditions.
- **Speculative resources**: undiscovered materials that may occur in either known types of deposits in favourable geological settings where no discoveries have been made, or in yet unknown types of deposits that remain to be recognised.

Source: Tietenberg (2000).

Factors influencing the stock classification include prices, extraction costs and technology. Current reserves are those that are known and can be economically extracted under present costs, prices and technology. Some demonstrated resources may be sub-economic and thus are not included as current reserves. However, increases in resource price, or improved extraction technology (to reduce mining costs) will shift these stocks into the current reserve category. Also, as exploration technology improves (often spurred by rising resource prices), new stocks may be discovered that will add to either economic or sub-economic stocks. The best example of shifting resource stocks is with petroleum. In the 1970s, when oil prices increased dramatically in the Middle East, petroleum companies increased their global search for petroleum, finding many new deposits. Also, the higher oil prices moved sub-economic petroleum stocks into the current reserve category, for example in the North Sea and the tar sands of Alberta, Canada. Over the decade following, the level of current global reserves increased significantly. One outcome in the late 1990s was a decline in crude oil prices as current reserves coming on stream exceeded global demand. A contributing factor was a partial breakdown of oil producing cartels.

What influences the rate of extraction from current reserves?[2] In addition to prices, costs and technology, the availability of substitutes and potential for re-use and recycling are important factors. If substitutes for fossil fuels become relatively cheaper, the demand for petroleum could decline. Biomass energy, electric cars and solar power are all examples of existing substitutes that are gradually becoming more competitive with fossil fuels. If recycling of specific minerals is possible, then the demand and extraction rates will also fall. As an example, it is more efficient to recycle aluminium than produce new aluminium from raw bauxite, which requires huge amounts of energy.

A major question relating to natural resources in the region is: how long and under what conditions can natural resources continue to support economic and social development? If natural resources are managed properly, they can contribute to development over an extremely long time period; some would argue indefinitely. From module 2, the rate at which natural resources are consumed, degraded, or conserved is a critical element of sustainable development. Of particular importance is how non-renewable resources are allocated and exploited. Module 2 suggested that a sustainable development strategy should involve investing income from non-renewable resources to build renewable resource stocks as well as investing in human and productive capital. The most significant challenge for managing non-renewable resources is determining an optimal level of extraction over time, while shifting to a greater reliance on renewable resources. With renewable resources, the management challenge is to create conditions for optimal harvesting that conserves sustainable stocks and flows.

5.2 ECONOMICS OF RENEWABLE RESOURCES

5.2.1 Introduction[3]

Renewable resources take many forms. Some, like forests, can be stored in the sense that the harvesting decision can occur at various times over the life of a stand of trees. Economics can help producers understand the optimal age to harvest a forest. Property rights in forestry for managed commercial stands are often efficient[4]. Other renewable resources such as

[2] This concept is explored in more detail later in the module.
[3] The following sections draw heavily from Tietenberg (2000).
[4] Refer to module 4 for details of efficient property rights.

communal forests and fish however, tend to occur under less efficient property rights regimes. While the biological growth functions for both forests and fish are basically similar, the economics of harvesting are slightly different. In this section, the biological and economic harvesting criteria will be examined for both types of resources, first with forests under an efficient property rights system, and then for fish under an open-access property right system.

5.2.2 Renewable Resources with Efficient Property Rights - The Case of Forests

a) Biological growth and harvesting

A stand of trees will have a growth and yield curve very similar to a typical production function in micro-economics[5]. Assume a new plantation is established on a certain area. When the trees in the stand are young, average growth rates will be very high. As the stand matures and develops into commercial timber, total stand volume is high but average growth rates are declining. As the old stand begins to decay and trees fall down, the total stand volume might even decrease (Table 5.1 and Figure 5.2). In Table 5.1, the mean annual increment (MAI) is a forestry term simply representing the total stand volume at any age divided by the age. The annual incremental growth (AIG) is the marginal growth, represented by the change in volume over a given time period (10 years in this case) divided by the time period. Figure 5.2 shows total stand volume over time. Growth rates are equal to the slope of the production curve. Using a biological decision rule, the forest would be harvested when the MAI is maximised, in this case between 110 and 120 years. This is roughly the time period when AIG begins to decline. The harvest period is also called the rotation age in forestry jargon.

b) Economic aspects of forest harvesting

The standard forestry biological harvesting criteria are devoid of economics. They fail to account for costs, revenues, and the time value of money reflected through a discount rate. From an efficiency perspective, the optimal time of harvest is when the net present value of the stand is maximised, not the MAI. Table 5.2 provides simple data based on the previous "biological" example. This time however, economic factors determine the optimal harvesting

[5] Refer to module 11 for basic micro-economic theory, including production.

period when net benefits are maximised. Case 1 shows costs and revenues that are not discounted, in other words, what a forester might follow. As expected, the optimal harvest point is 120 years, where the MAI and stand volume are highest.

Discounting revenues and costs provides a different result. At a one percent discount rate, the optimal harvesting point is at 110 years. At a two percent discount rate, the optimal harvesting point is 90 years. Changing the magnitude of harvesting costs and timber revenues will not change the optimal harvesting point. On the other hand, altering the discount rate does have a powerful influence on the optimal harvesting point. As the discount rate increases, the optimal harvesting point decreases because of the higher opportunity cost of delaying harvest revenues. In the example above, a discount rate of three percent renders all possible harvesting points with a negative net benefit. Where forests take many decades to mature and revenues are fairly low, the economics of forestry is often not positive. The rational economic (as opposed to environmental) response is to harvest the forest and not replant. This simple case illustrates that in most cases, the economic harvesting point is less than the biological point.

Table 5.1: Stand age and volume table for commercial forest

Age	Volume	MAI	AIG
(Years)	M^3	M^3	M^3
10	75	8	8
20	180	9	8
30	325	11	10
40	480	12	11
50	650	13	12
60	850	14	13
70	1100	16	14
80	1400	18	16
90	1900	21	19
100	2400	24	22
110	2800	25	23
120	3000	25	22
130	2850	22	19
140	2600	19	16

Note: MAI – mean annual increment, AIG = Annual incremental growth

Source: Adapted from Tietenberg (2000).

Figure 5.2: Model of biological tree growth