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DESERTIFICATION, PRODUCTIVITY AND

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INTRODUCTION

The United Nations Convention to Combat Desertification (UN-CCD) defined desertification as the degradation of land in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities (1). Desertification is not a new problem, but one that traces back to 2200 BC and the degradation of Mesopotamia (2). However, the estimated extent of degradation of the world's dry lands at the beginning of the 3rd millennium is staggering (3) (Table 1). Though estimates of the magnitude of degradation vary widely, it is generally accepted that at least 60% of the world's 2556 mha of rangelands are at least moderately desertified (4). It should also be noted that these estimates often do not consider lands outside the world's subtropics (5). Globally, about 1 of every 6 ha of land has degraded soils as a result of disturbances such as overgrazing, deforestation, and overexploitation for domestic uses (6). The UN-CCD (1) estimates that over 250 million people are affected by desertification with about one-sixth of the world's population at risk. Generally, the effects of this land degradation are reductions in desirable plant production, alterations in biomass, lowered carrying capacities for livestock, increased soil erosion, and an overall increase in environmental deterioration (7). It is usually assumed that desertification has direct and measurable effects on either primary or secondary production from these lands. In very severely desertified situations, such as southern Kazakhstan, productivity has been dramatically reduced (8). For other regions of the world where desertification is certainly serious but not severe the relationships between degradation and productivity are less obvious and direct. These relationships need to be understood so that measures other than simply productivity reductions are employed to accurately assess rates, extent, and threats of degradation to these land resources.

PRIMARY PRODUCTIVITY

Primary productivity is defined as the fixation of carbon dioxide into organic molecules by photosynthetic organisms.

Typically, agriculturally and ecologically based estimates of primary productivity focus on some aspect of annual above ground net primary productivity (ANPP). For crop lands this may be annual grain yields, and reductions in yield of 25% or more have been reported for dry land and irrigated crops (3). Often, these losses in productivity are coupled to increased soil erosion due to degradation. For rangelands, primary production is often expressed as biomass production on a dry matter basis per some unit area. Plant processes affected by degradation include reproduction, germination, establishment, survival, and competition, and adverse effects on these processes can result in reductions in ANPP. As a result, there are a number of documented reports from different continents where these shifts have resulted in large declines in primary productivity (9). Yet, the initial effects of chronic disturbances on these processes may result in structural changes in vegetation such as a shift from herbaceous to woody dominated plant communities, and these structural changes do not always result in reductions in primary productivity (10, 11). For example, in the northern Chihuahuan Desert of North America, ANPP does not differ among major vegetation types, including shrub land types that are regarded as degraded from the historic desert grasslands (12). These types do differ in other vegetation attributes including species richness and in their seasonality of production. Irrespective, seasonal measures of primary production in heterogeneous environments are extremely variable both temporally and spatially (13). Thus, it is difficult to consistently and directly equate reductions in primary productivity in all rangeland environments with desertification.

SECONDARY PRODUCTIVITY

Secondary productivity is the transfer of energy from primary producers to consumers, and is often expressed as animal production. For the world's rangelands secondary production is often measured in terms of livestock productivity. There are specific instances where deserti-

Table 1 Global desertification in drylands (arid, semiarid, and dry subhumid regions)

Continent	% Degraded of total area		
	Irrigated land	Rainfed cropland	Range land
Africa	18	61	74
Asia	35	56	76
Australia and New Zealand	13	34	55
Europe	16	54	72
North America	28	16	85
South America	17	31	76

(From Ref. 3.)

fication has resulted in a documented decline in livestock stocking rates, such as in the Western Cape of South Africa (14). However, in many instances losses of stocking rates have not been directly linked to desertification, and loss of secondary productivity can be an ineffective indicator of degradation (3). For example, looking more broadly at South Africa during the last half of the 20th century livestock numbers have been fairly stable (15). A more effective indicator of desertification may not be the total number of livestock, but the shift in livestock species used as vegetation types typically change from herbaceous to more woody species with degradation (16).

CONCLUSIONS

Despite the increase in desertified lands during the 20th century, the world's populations of grazing livestock, primarily cattle, sheep, and goats, have collectively increased 1% annually since World War II (17, 18). This is an increase of 1.1 billion head of livestock over the past five decades, and the increase has been spatially heterogeneous. For example, cattle numbers have more than doubled in Africa, South America, and Eastern Europe, a rate more than 50% higher than the global average. Seventy-seven percent of the global increase in sheep numbers has occurred in Asia. Yet, these continents have reported extensive desertification during this century. Declines in numbers of livestock may be misleading as an indicator of desertification at regional, national, and continental scales.

Hoffman (19) has described five phases of vegetation change during the degradation of the Karoo in South Africa. These were: 1) primary degradation with a loss

of cover, primarily palatable perennial grasses and shrubs, 2) denudation with further loss of palatable plants, an increase in unpalatable species, and accelerated rates of erosion, 3) revegetation with an increase in unpalatable species, particularly woody plants, 4) secondary degradation with a relatively stable community of undesirable plants, and 5) desertification with loss of most plant species other than a few hardy shrubs, a soil surface widely exposed to accelerated erosion, and invasion by exotics. Similar vegetation dynamics have been described for other dry land environments in response to overgrazing and prolonged drought. Throughout several of these phases primary and secondary productivity may or may not be reduced. In general, effects of desertification on primary or secondary productivity of rangelands will be related to resulting species alterations and/or changes on water and nutrient economics (20).

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