

ASSESSING THE VALUE OF FARMLAND ON THE BASIS OF NATURAL RESOURCE CRITERIA IN NAMIBIA

II. SUGGESTIONS FOR A NAMIBIAN SYSTEM

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ABSTRACT

In modern economies land has become a production factor at the same level as capital and labour. Land is desired, there is competition for it, especially under circumstances when it becomes scarce, and it acquires value. A functional land market is developing almost worldwide. In a companion article an attempt was made to introduce viewpoints on how to assess the value of land as applied in a number of other countries, with comments on their limitations. In this article we shall attempt to define the most relevant factors in a Namibian context, and to quantify their impact on the market value of land. Proposed ratings are tentative and open to improvement. Readers are invited to provide feedback, adaptations or alternative suggestions. Because of the predominance of ranching in the country, the focus in this exercise will mainly be on rangeland.

FACTORS AFFECTING THE LAND USE POTENTIAL FOR RANCHING IN NAMIBIA

Grazing capacity is primarily defined by total grass biomass production, palatability/quality of grass cover, and the amount of plant biomass required per animal. The natural resource-based factors that influence ranching value in Namibia can, therefore, be grouped into three main clusters:

- natural climatic and soil conditions affecting grass growth and fodder production, both in terms of quality and quantity;
- availability of drinking water for animals; and
- specific natural conditions related to vegetation control, bush encroachment and the occurrence of poisonous plants.

Access to markets, size of management unit and improvements to farm infrastructure can be considered as additional non-resource based factors influencing the market value of the land. This is also the case for alternative non-agricultural sources of income, e.g. eco-tourism, trophy-hunting, camping facilities, hiking trails, etc., and well-established cottage crafts among local people and families of farm workers, such as weaving of karakul carpets.

When evaluating land, it should always be in connection with a particular land use. It may be the present land use, or a potential future land use. In such cases, the criteria rating should be carried out for both current and potential future land uses, and the scenarios compared to decide on the optimal use that piece of land can be put to.

RAINFALL REGIME

Rainfall and temperature regimes can be considered the uppermost climatic factors in ranching. They directly affect biomass production in terms of quantity and quality of the grasses and fodder; indirectly, they are responsible for erosion hazards and the development of adverse vegetation types that restrict grazing areas.

The rainfall regime involves three main components: amount and distribution of rain, and rainfall risk. The first two are well expressed in the nature and the length of the growing period, which is a simulation of the crop growth season based on averages and point station data. This information is well documented in the Growing Period Map of Namibia (De Pauw and Coetzee, 1999; De Pauw *et al.*, 1999).

The growing period (GP) is defined as the period in the year when precipitation is higher than half potential evapotranspiration - this being an expression of the water consumptive use of an average grass cover - extended by the time that soil moisture storage is depleted, and at times when the mean air temperature is above 6.5°C (FAO, 1978).

Length of growing period:

The length of the growing period (GP) (in days) is a good indicator of the time that biomass can be built up without major moisture and temperature stress. It matches also the length of the phenological growth stages of the various crops and, therefore, permits also a selection of those. In this sense, the length of the growing period is a direct factor affecting the land suitability for pasture and fodder production.

Evaluation of the relative importance, in particular with respect to the definition of conditions of optimal and marginal length of GP, is illustrated in the table below. A GP-length of more than 120 (up to the maximum of 140-150) days allows maximal grass (biomass) production in the country and fits as well the growth requirements for fodder production (sorghum and millet in particular); it is however somewhat too short for optimal maize growth. This type of GP, corresponding to zone 1 of the Growing Period Map for Namibia (De Pauw and Coetzee, 1999; De Pauw *et al.*, 1999), allows therefore for an optimal rain-fed production (90-100% of potential yields) for those land use types.

The following table displays the suitability classification for ranching in Namibia as a function of length (in days) of the growing period (Verheye, 1997).

LAND USE TYPE	DEGREE OF CONSTRAINTS			
	NONE	SLIGHT	MODERATE	SEVERE
GRASSLAND FOR CATTLE BREEDING	120+	91-120	61-90	60-
GRASSLAND FOR SMALL STOCK	90+	61-90	31-60	30-
FODDER MILLET	90+	61-90	60-	n.a.
SORGHUM FODDER		120+	91-120	61-90
MAIZE FODDER	n.a.	120+	91-120	90-

A GP of 91-120 days (corresponding to zone 2 of the GP Map of Namibia) remains optimal for small stock grass production and for millet-fodder (90-100% of potential yields), but shows slight limitations for large stock breeding, as well as for sorghum cultivation. It has moderate limitations for maize production. In practice this means that rain-fed maize cultivation is no more profitable on soils with very low moisture holding capacities.

A growing period length of 61-90 days, corresponding to zones 3 and 4 of the GP Map of Namibia, has slight limitations for small stock and millet, and moderate limitations for large stock breeding and sorghum cultivation; the area is already out for reasonable rain-fed maize cultivation.

A growing period of 31-60 days (corresponding to zones 5,6 and 7 of the GP Map of Namibia) has severe limitations, e.g. less than 40% of anticipated yield and generally no more profitable, for all land use types except for extensive small stock grazing. A growing period of less than 30 days corresponds to zones 8 to 11 of the GP Map of Namibia and allows only small stock and game farming in extensive farming systems, with rather severe limitations requiring adapted management techniques to remain profitable.

These different suitability levels in terms of **length of growing period (GP)** can be given the following numerical rating:

GP 1:	suitable land, corresponding to areas without constraints, is given a rating of 1000 points;
GP 2:	moderately suitable land (with slight constraints) is valued 750 points;
GP 3:	marginally suitable land (with moderate limitations) is rated 500 points; and
GP 4:	unsuitable land (severe limitations) is rated 250 points.

Nature of Growing Period:

The **nature of growing period** reflects the continuity of the moisture availability to plants. It is specified by the **rainfall risk factor (RR)**. An important aspect is the irregularity of rainfall distribution, which has been a critical factor in the last decade in the Southern Hemisphere due to the adverse effects of El Niño. Not only does it shorten the growth cycle, but it is also responsible for intraseasonal dry spells, with a negative effect on biomass production. Rainfall variability adversely affects ranching and crop production in different ways. If the

dry period is not too long a stock-farmer with a good financial basis can hand-feed his herd, rent grazing facilities somewhere else or de-stock by marketing his animals. However, de-stocking inevitably means it will take a few years for full recovery of the breeding herd. While the recovery cycle is shorter for crop farmers, a 10-day dry spell at a critical time can cause complete crop failure for dryland-maize. Crop farmers thus stand to lose both their income and expensive inputs such as fuel, seed, fertilizer and herbicides, in one stroke.

Two types of rainfall variability can be registered: temporal and spatial variability. The impact of temporal variability can only be assessed from the study of long-term rainfall series, for which good data is available in Namibia. Spatial variability is difficult to register. The higher the rainfall variability the higher the need for a larger farm size, an increased number of boreholes and more provision to be made for fodder production. In this respect, rainfall variability increases the cost of farming.

The relative importance of the **rainfall risk (RR)** can be expressed in terms of the coefficient of variability of rainfall, which is defined as the ratio between the standard deviation (in its turn defined as the root-mean-square of the deviations from the arithmetic mean) and the arithmetic mean, expressed as a percentage. In Namibia the CV of mean and median annual, season and monthly rainfall varies between $\pm 30\%$ in Caprivi and Kavango to more than 100% in the Namib. A penalty can be applied to the ratings defined above for the length of growing period by subtracting a number of points. Hence, the following rating scale is proposed:

RR 1: CV less than 30%:	no penalty applied;
RR 2: CV between 30 and 40%:	subtraction of 25 points;
RR 3: CV between 40 and 50%:	subtraction of 50 points;
RR 4: CV between 50 and 60%:	subtraction of 75 points.
RR 5: CV more than 60%:	subtraction of 100 points.

Temperature regime:

Grass growth is seriously reduced or virtually stopped at temperatures below 5°C or above 35°C; for millets, sorghum and maize the lower limit is generally around 10°C. In this

respect, temperature influences the types of crops that can be grown, as well as the growth rate of natural vegetation.

Low winter temperatures appear to be positive for reducing bush encroachment, because one of the main encroachers, *Dichrostachys cinerea* (sickle bush), cannot stand frost (De Klerk, 2002; Venter & Venter, 1996).

The dormancy period of grasses is initiated and more affected by the first frost or the first cold snap in the year, rather than by the end of rains. At the end of winter, grass starts growing after the first rains and not so much when temperature rises. Bush, on the other hand, will come into flower as soon as the temperature rises, provided that there is some stored moisture available in the soil. In conclusion, temperature triggers some of the most important physiological changes in both grass and browse species. However, these effects have not yet been quantified properly in Namibia and neither are good enough temperature records available to include temperature here to substantiate and quantify the role of temperature in affecting land use potential for ranching in Namibia. It is nevertheless a field that needs more research attention and ought to be included in future in this list of natural resource criteria for land evaluation, as information becomes available.

INHERENT SOIL CHARACTERISTICS

Soil properties influence crop growth through four major parameters linked to water and nutrient supply, root development and aeration. Those qualities are expressed by five directly measurable or observable soil characteristics:

- soil texture,
- profile depth,
- drainage,
- soil pH and
- salinity/sodicity hazards.

Soil texture:

Soil texture (TE), together with profile depth, has an impact on the water storage in the root zone, with figures that may range from less than 50 mm/meter of soil with sandy textures to more than 200 mm for deep loams and loamy clays. Texture is also an indicator of the amount of nutrients that can be fixed and kept at the disposal of plant roots. In this respect a differentiation can be made between three main textural classes in Namibia. Because texture may have either a positive effect (good water storage by clayey or loamy soil) or a negative effect (too high permeability of sands) this double-sided effect is reflected in a bonus (adding 50 points) for the TE1 soils, a neutral position (no adding, no subtraction) for TE2 soils and a penalty (subtracting 50 points) for TE3 soils:

TE 1: medium-textured soils developed over limestones and other carbonaceous rocks; they have a clay content between 15 and 45%, good aeration and good water holding capacity; in

most cases the free lime is below 10-15%; they have no limitation for pasture, nor for fodder production; addition of 50 points

TE 2: other soils with a clay content above 15%; they occur most frequently in the lowlands, and have intermediate chemical and physical properties between units TE1 and TE3; they are considered moderately suitable for both pasture land and fodder growth; point neutral

TE3: sandy soils, often associated with the formation of Kalahari Sands; their clay content is below 10%; they have a low nutrient status and moisture retention capacity; they are moderately/marginally suitable for grassland, millet and sorghum, and unsuitable for maize; subtraction of 50 points

Soil depth:

With respect to **soil depth (DE)** a differentiation can be made between 4 depth classes. Corresponding point ratings are operated on the same principles as explained above:

DE 1: very deep soils (more than 100 cm deep) are considered optimal for plant growth; they have no suitability limitations; the point rating is upgraded with 100 points;

DE 2: moderately deep soils have a depth of 50-100 cm, and have no limitations (suitable) for grass, very slight limitations (suitable) for millet and sorghum, and moderate limitations for maize (moderately suitable); the point rating is upgraded with 50 points for grass, remains unchanged for millet and sorghum and is downgraded by 50 points for maize.

DE 3: shallow soils (20-50 cm depth) have an adverse effect on both root development and moisture storage capacity, especially in drought-prone areas; they are therefore suitable for grass growth, moderately suitable for millet and sorghum, and marginally suitable for maize; the point rating is unchanged for grass, downgraded by 50 points for millet and sorghum and downgraded by 100 points for maize.

DE 4: very shallow soils (0-20 cm deep) are moderately suitable for grasses and unsuitable for other crops; the point rating is downgraded by 50 points for grassland and by 100 points for fodder grains.

Soil drainage:

Soil drainage or wetness status (**DR**) is an indicator of permeability and aeration of the root zone. A groundwater table at shallow depth may provide additional moisture to crops through capillary rise. Four suitability classes can be

differentiated, with corresponding point adjustments in relation to their relative impact on growth and production. Point adjustments correspond to the relative impact of the drainage on growth and production conditions:

- DR 1: excessively drained soils with a ground water table below 2 m; they do not benefit from capillary moisture and can therefore be considered as moderately to marginally suitable; this unit is point-neutral for deep-rooted fodder crops, while it is penalized by 50 points for grassland which has only a shallow-rooting pattern that cannot reach the deep moisture;
- DR 2: well-drained soils with a ground water table between 0.8 and 2 m; they combine the positive effects of good aeration and a slight capillary moisture supply, and are therefore considered suitable; the unit is point-neutral for both grassland and fodder grains;
- DR 3: imperfectly drained soils, with a water table between 30 and 80 cm; though they have a good moisture supply these soils are rapidly affected by structural deterioration due to trampling, and after every major rain storm they cause access difficulties; these soils often possess features of sodicity and/or salinity; they are considered marginally suitable; this unit is penalized by 25 points for grassland, by 50 points for fodder millet and sorghum, and by 100 points for fodder maize.
- DR 4: waterlogged soils for most of the year; they are only temporarily suited for pasture and unsuitable for any other cropping; the unit is penalized by 100 points for grassland and by 200 points for fodder grains.

Soil pH or acidity:

Soil pH (PH) is an expression of the soil nutrient status and nutrient availability to plants. Additional information has to be acquired through data on the nitrogen-phosphorus-potassium (NPK) status and cation exchange capacity, but such data is often not available for Namibian soils. The following classification and point ratings for the pH soil status are proposed:

- PH 1: soils with pH (water) in the root zone between 6.5 and 7.2 are slightly acid to neutral and are considered highly suitable; all land use types are upgraded with 25 points;
- PH 2: soils with a pH between 5.5 and 6.5 and between 7.2 and 8.5 are either moderately acid or alkaline; the latter include often free carbonates but have no toxic sodium in the root zone; they are considered moderately suitable; the rating is point-neutral.

- PH 3: soils with a pH between 4.8 and 5.5 are acid; they are marginally suitable for most crops; all land use types are penalized with 25 points; the pH status can easily be improved by a proper lime amendment.
- PH 4: soils with pH above 8.5 or below 4.5 include generally toxic elements like sodium or aluminium and show a limited nutrient uptake; a pH amendment is, nevertheless, technically possible; grassland is penalized with 50 points, fodder grain cultivation by 75 points.

Salinity and sodicity:

Salinity and sodicity (SA) have an adverse effect on crop and grass growth and therefore depreciate substantially the production potential of the land. Both adverse conditions can, however, be reclaimed through adapted management. The following classes and adapted factor ratings can be taken into consideration:

- SA 1: non-saline and non-sodic soils; electric conductivity is below 2 mmhos/cm and exchangeable sodium percentage (ESP) is below 15; highly suitable; factor rating is point-neutral;
- SA 2: slightly saline and variably sodic; electric conductivity is between 2 and 4 mmhos/cm; slight limitations and moderate suitability; a penalization of 25 points is applied for all land use types;
- SA 3: moderately saline and variably sodic; electric conductivity is between 4 and 8 mmhos/cm; moderate limitations and marginal suitability for grasses, the composition of which will change and be less palatable for cattle, and for millet and sorghum; unsuitable for maize; a penalization of 50 points for grasses and sorghum/millet and 100 points for maize fodder is applied.
- SA 4: very saline and/or sodic; electrical conductivity is above 8 mmhos/cm and/or ESP is above 30; unsuitable; a penalization of 150 points is applied for all land uses.

SECONDARY SOIL AND LANDFORM FACTORS

Those refer in particular to slope and the presence of surface stones and rockiness. Although they can be considered as natural physical land factors, they affect especially land management conditions. Slope is often at the origin of erosion, creating water runoff and the loss of nutrients in the topsoil layers. Surface stones and rockiness reduce the surface which can be grazed and, moreover, make mechanical maintenance of the land more difficult.

Slope gradient:

In terms of **slope gradient (SL)** the following three main units can be distinguished:

- SL 1: slopes between 0 and 3%, without any traces of water or wind erosion; no limitations; no downgrading on the rating scale;
- SL 2: slopes between 3 and 10%; slight limitations; no downgrading for pasture; a downgrading of 25 points for fodder crops is applied;
- SL 3: slopes above 10%; moderate limitations; a penalty of 25 points for pasture and of 50 points for grain fodder is applied.

Stoniness and rockiness:

For **stoniness and rockiness (SR)** the following tentative suitability classes and point ratings can be proposed:

- SR 1: less than 3% of stones or rock outcrops; no limitations; no point downgrading applied;
- SR 2: between 3 and 15% of stones and/or rock outcrops; suitable for grassland, marginally suitable for arable cropping; no downgrading for pasture; a downgrading of 25 points for grain fodder is applied;
- SR 3: between 15 and 40% of stones and/or rock outcrops; moderately suitable for grassland, unsuitable for arable cropping; a downgrading of 25 points for pasture and of 50 points for grain fodder is applied;
- SR 4: more than 40% of stones and/or rock outcrops, marginally suitable for pasture and unsuitable for grain fodder; downgrading of 50 points for pasture and 100 points for grain fodder.

DRINKING WATER FOR ANIMALS

In rural Namibia, drinking water for animal and human consumption comes almost exclusively from groundwater. Surface water availability is very limited both in space and time, due to low and poorly distributed rainfall and high evaporation rates. Thus, availability and quality of groundwater are of paramount importance for the reasonable exploitation and the inherent value of land in the country. We suggest that one should take the depth, yield and quality of groundwater in account as criteria for land evaluation. The actual waterpoint density on a farm is considered in terms of the distance that animals have to walk to get to water. Looking from the other side, the waterpoint density determines the area on a farm that can actually be grazed by animals (within a particular radius from water).

Water availability:

Average water requirements for indigenous breeds of livestock in semi-arid areas are estimated at 25-45 l/day every

3-4 days for cattle and at 3-6 l/day every 2-7 days for sheep (FAO, 1991). The evaluation of water availability from depth of the groundwater table and yield of borehole is made on the basis of the requirements above and on the assumption that the deeper the borehole the higher the drilling and pumping (exploitation) costs. The following tentative classes for **water availability (WA)** have been considered:

- WA 1: water available at less than 5 m deep (including surface water) and/or a yield of more than 5 m³/h; no limitations; upgrading by 50 points;
- WA 2: water available at depths between 5 and 40 m and/or a yield of less than 5 m³/h; slight constraints; point-neutral;
- WA 3: water available at 40 to 100 m; moderate limitations; downgrading by 75 points;
- WA 4: water available at more than 100 m depth, or no available water; severe constraints; downgrading by 150 points.

Water quality:

With respect to **water quality (WQ)** a distinction must be made between the quality of drinking water for human and animal consumption. While the critical limit for the former is set at 250 micromhos/l, it is generally accepted that the limiting quality for stock watering is in the range of 3,000-10,000 mg of total dissolved salts (TDS) per liter. Even more saline water may be used in some seasons. Water containing up to 10,000 TDS/l is not harmful, provided the proportion of bivalent cations and anions, notably magnesium sulfate and carbonate, is low (FAO, 1991). The following 4 suitability classes and corresponding point ratings are tentatively proposed:

- WQ 1: electrical conductivity of the water (EC) below 250 micromhos/cm and sodium adsorption ratio (SAR) is below 10; suitable for both human and stock consumption; no limitations; point upgrading by 50 points;
- WQ 2: EC between 250 and 750 micromhos/cm and SAR below 18; moderately suitable for stock consumption; slight limitations; point-neutral;
- WQ 3: EC between 750 and 2250 micromhos/cm and SAR below 26; marginally suitable for stock consumption; moderate limitations; downgrading by 50 points;
- WQ 4: EC above 2250 micromhos/cm and SAR above 26; unsuitable; downgrading by 100 points.

Watering points:

Natural water shortage can to some extent be overcome by sinking additional boreholes, considered as an indicator of good management. The presence of a network of boreholes adds to the commercial value of pasture land. The cost of erecting waterpoints would be brought into consideration when valuing the infrastructure, which is outside the scope of

this paper. FAO (1991, op. cit.) refers to critical limits of respectively less than 2 km, 2-5 km, 5-10 km and more than 10 km daily walking distance for cattle to drinking points as an indicator for no, slight, moderate and severe limitations in ranching. In line with these data the following classification for **borehole density** or **watering points (WP)** can be proposed:

- | | |
|-------|---|
| WP 1: | less than 1000 ha for one borehole, no constraints; upgrading by 50 points; |
| WP 2: | between 1000 and 2000 ha per borehole; slight limitations; point-neutral; |
| WP 3: | between 2000 and 8000 ha per borehole, moderate limitations; penalization by 50 points; |
| WP 4: | more than 8000 ha per borehole; severe limitations; downgrading by 100 points. |

VEGETATION CONTROL

The more pasture land available within the land property, the better for the ranching system. Besides grassland there are also areas covered by vegetation that are not useful to the animals. The control of such adverse vegetation cover refers in particular to bush encroachment and the occurrence of poisonous plants.

Bush encroachment:

Rangeland degradation due to **bush encroachment (BE)** is a major problem in Namibia. All the savanna veld types north of 23° North latitude in the country (approx. 17 million ha) are subject to some form of bush encroachment. It is believed that the phenomenon, where it causes severe losses in livestock productivity, extends at present over 8 to 12 million ha (Bester and Reed, 1997, Bester, 1999).

The major species causing the encroachment problem are *Acacia mellifera* (Black thorn), *Dichrostachys cinerea* (Sickle bush), *Terminalia sericea* (Silver Terminalia), *Terminalia prunioides* (Purple pod Terminalia), *Acacia erubescens* (Blue thorn), *Acacia reficiens* (False umbrella thorn) and *Colophospermum mopane* (Mopane). *Prosopis* varieties occur mainly in the Nossob-, Olifants- and Auob rivers in high densities and they have started spreading outside the riverbeds into the Kalahari. Large areas in the southern parts of the country are affected by *Rhigosum trichotomum* (Driedoring) and *Acacia mellifera*. The distribution of sickle bush is affected by winter temperatures, as seedlings are sensitive to frost (De Klerk, 2002, Venter & Venter, 1996).

Bush encroachment has a double adverse effect on grassland production in the sense that it reduces areas for palatable grass growth and that it creates severe competition for available soil moisture and nutrients. Hence, it results in a decrease of the carrying capacity of the affected areas. Where bush has been controlled, grass tends to remain green longer, which is an added advantage (Bester, 2002)

Carrying capacities in the country have declined between 20 and 80% over the past two to three decades. Bester and Reed (1997, op. cit.) report that in the Thornbush Veld of Otjiwarongo, the average carrying capacities for large stock units have dropped from 10 ha in 1970 to 15-20 ha per head of cattle nowadays. In the Karstveld Savanna carrying capacities have declined from 1 large stock unit (LSU) per 8 ha to the present situation of 1 LSU per 15-20 ha. The average bush densities in the Thornbush Veld and Karstveld are estimated at 6,000 and 10,000 bush/ha respectively, but densities up to 14,000 and 20,000 respectively had been recorded in those areas.

Methods of controlling bush encroachment are of mechanical, biological or chemical nature and all involve high cost. Mechanical control is the most expensive and goats must be used with caution, as they can quickly upset the ecological balance completely (Bester, 2002). All these methods require after-care, which can be a continuation of the original control method or a combination of methods. Herbicide treatment is by far the most effective and shows fastest results. Although these chemicals break down into harmless products soon after application, there is a worldwide groundswell of emotion against the use of chemicals in the production of food, and thus chemical control of bush could have negative implications for the marketing of 'organically produced beef', especially to Europe. It has, however, major consequences in production potential. Research results with aerial application of herbicides (with a 50% kill) indicated an increase of 100-200% in grass production, and hypothetically increased animal production worth an estimated N\$ 400million. This ballpark figure had been calculated as follows: 17 million ha x 4 kg live weight/ha increase x N\$ 5.00/kg live weight = N\$ 340million per 100% increase in grass production. (De Klerk, 2002).

Bush control is extremely costly and therefore calls for important investments. In the late 1980's the cost of killing 2,000 stems was ±N\$ 140-260 depending on the method used, and at that time the cost of aerial application of herbicides was 3 times higher than the market value of land. At present, manual stem treatment with herbicides varies between N\$ 200 and N\$ 400 per ha, depending on the soil type. Aerial applications are between N\$ 154 and N\$ 230 per ha. For manual clearing the present costs vary between N\$ 150 and 200 per ha. Overall, costs are dependent on bush density, soil type (especially clay content) and degree of bush thinning.

At present, the agricultural economic value of land in the Tsumeb, Otavi and Otjiwarongo districts is in the vicinity of N\$ 100-120, N\$ 140 and N\$ 180 respectively, although the market values are substantially higher. Farmers claim that, under those conditions, bush control with herbicide or mechanical means should not cost more than N\$ 150 per ha (De Klerk, 2002). Only farmers owning more than 8000ha have the economy of scale to afford to remove encroaching bush (Dahl & Nepembe, 2001). It will be difficult to achieve this operation at such low costs in areas where bush densities are in the order of 10,000 stems per ha and on soils with high clay content.

In the light of the foregoing it is suggested that the importance of **bush encroachment (BE)** be estimated as follows (figures are in line with the criteria used by Agribank):

BE 1:	less than 1,000 bushes/ha, no constraints; point-neutral;
BE 2:	1,000-2,500 bushes/ha; slight constraints; moderately suitable; point depreciation of 50 points;
BE 3:	2,500- 5,000 bushes/ha; moderate constraints; marginally suitable; point depreciation of 100 points;
BE 4:	more than 5,000 bushes/ha; severe constraints; point depreciation of 150 points.

Occurrence of poisonous plants:

Some vegetation can produce certain toxic chemical components without direct ill effects, unless an excessive amount of the plant material is grazed by animals. Other plants are directly poisonous because of their inherent composition. Most poisonous species in Namibia are of the second type. They include most frequently the following species: *Urginea burkei* (Transvaal slangkop), *Dichapetalum cymosum* (gifblaar), *Dipcadi glaucum* (malkop-ui) *Geigeria ornativa* or *africana* (vermeerbos) and *Crotalaria burkeana*. (Van der Merwe & Norval, 2002; NBRI, 2002)

Plant poisoning is most common when food is scarce, such as during droughts or in the beginning of the rainy season. It mainly occurs at the foot slopes of hills and dunes, where such plants develop faster than the surrounding grasses and, hence, are a direct target for grazing cattle.

The development of poisonous plants in specific locations of the landscape is most probably related to special soil types, but the exact reason is not known. Treating this issue is in the first place a management problem: the area has to be camped off for a critical period of the year when grass is still scarce, or casual labourers have to be paid to dig out the bulbs. These management options demand additional expenses, while ignoring the problem either incurs financial losses in association with stock losses, or in effect decreases the area of the farm available for grazing.

In line with the figures advanced in the valuation formula used by the Agribank the following suitability classes for the occurrence of **poisonous plants (PP)** are proposed:

PP 1:	no poisonous plants present on the farm, no constraints; point-neutral;
PP 2:	less than 10% of the land affected, slight constraints; downgrading by 25 points;
PP 3:	10-50% of farmland affected; moderate constraints; downgrading by 75 points;
PP 4:	more than 50% of farmland affected; severe constraints; downgrading by 150 points.

NON-RESOURCE-BASED MANAGEMENT FACTORS

Those refer in particular to the minimum size of the farm and accessibility to the major road system for evacuation to markets. Size of farm is closely related to rainfall risk, and the amount of effectively available grazing land (see above) and the economic viability of the management unit. Areas with a high rainfall risk need the possibility to transfer the flock from drier areas to better grasslands and/or to increase the need for more fodder production. The definition of an economically viable farm unit is still a matter of debate between the Ministry of Agriculture and the farmers' associations, and it is outside the scope of this paper.

EVALUATION PROCEDURE

The evaluation procedure implies the simple application of the formula below, and the completion of the different numerical values for each parameter involved, following the directives from the tables above.

$\text{Value index} = \text{GP} + \text{RR} + \text{TE} + \text{DE} + \text{DR} + \text{PH} + \text{SA} + \text{SL} + \text{SR} + \text{WA} + \text{WQ} + \text{WP} + \text{BE} + \text{PP}$
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The first step in the exercise is to locate the farm or the piece of land under consideration in its particular growing period zone. This can be done on the Growing Period Zones Map of Namibia. The corresponding growing period zone is then given a numerical rating between 250 and 1000 points (see GP and RR ratings). Subsequently, an overview is made of the different soil characteristics in terms of texture (TE), depth (DE), drainage (DR), pH (PH) and salinity/sodicity (SA), and their relative rating adjustments applied. A similar exercise is done for the secondary soil and landform factors (SL and SR), drinking water characteristics (WA, WQ and WP) and 'problem' vegetation parameters (BE, PP). The value index has to be ranked on a rating scale from 0 to 1000.

The exact definition of the rating scale can only be properly established through a trial and error approach, and only after at least 15-20 farms with known sales value have been rated. These farms should by preference be located in different ecological zones, i. e. in areas with major differences in production potential.

In principle, the validation of this scale should be operated at two parallel levels. The first one compares farms with variable soil and vegetation characteristics in one and the same climatic or growing period zone. The second one compares farms with similar soil and vegetation properties, but located in different growing period zones. The first exercise would then permit the validation in particular of the soil parameters, the second one should focus more on the growing period impacts.

The following is a practical illustration on how to apply the procedure. Take an example of a piece of land under natural pasture with the following properties: Location in an area with a length of growing period (GP) of 100 days, with

coefficient of variability in seasonal rainfall of 35% (RR), with medium texture over limestones (TE), an average soil depth (DE) of 50-100 cm, well drained (DR) land, having a pH of 6.3 (PH), no salinity or sodicity (SA). Average slope (SL) is 2% and there are no stones, nor rocks (SR). Drinking water is available at 30 m depth (WA), with rather good quality (280 micromhos/cm)(WQ), and there is a borehole density (WP) of one per 2300 ha. In sector A the bush encroachment and occurrence of poisonous plants is <1000 bushes/ha and 5% respectively, in sector B this is 3500 bushes/ha and 35% respectively.

Matching of these data with the rating scales in paragraphs 3-8 allows the calculation of the following value indexes:

$$\begin{aligned} \text{For sector A: VI} &= \text{GP2} + \text{RR2} + \text{TE1} + \text{DE2} + \text{DR2} + \\ &\quad \text{PH2} + \text{SA1} + \text{SL1} + \text{SR1} + \text{WA2} + \\ &\quad \text{WQ2} + \text{WP3} + \text{BE1} + \text{PP2} \\ &= 750 - 25 + 50 + 50 + 0 + 0 + 0 + 0 + 0 \\ &\quad + 0 + 0 - 50 + 0 - 25 \\ &= 750 \text{ points} \end{aligned}$$

$$\begin{aligned} \text{For sector B: VI} &= \text{GP2} + \text{RR2} + \text{TE1} + \text{DE2} + \text{DR2} + \\ &\quad \text{PH2} + \text{SA1} + \text{SL1} + \text{SR1} + \text{WA2} + \\ &\quad \text{WQ2} + \text{WP3} + \text{BE3} + \text{PP3} \\ &= 750 - 25 + 50 + 50 + 0 + 0 + 0 + 0 + 0 \\ &\quad + 0 + 0 - 50 - 100 - 75 \\ &= 600 \text{ points.} \end{aligned}$$

This exercise indicates that, though the environmental conditions in terms of soil and climate are identical, sector A has a higher sales value than sector B due to the adverse effects of bush encroachment and the presence of poisonous plants. Obviously, the market price of both sectors will vary accordingly.

CONCLUSION

The system presented in this paper is relatively innovative in the sense that it has never been applied elsewhere. The principles of the approach are however well-known and have been successfully incorporated in valuation formulas in the German *Bodenschätzung* since 1934 as well as in the Belgian and Dutch re-allotment programmes, which have been operational for almost 35 years. They were preferred over the common economic methods that include too much subjective elements.

The main advantage of the approach here presented is that it is based on objective criteria that can be observed and

controlled by all those who directly or indirectly deal with natural resources and with production aspects of land. It is completely transparent and excludes all subjective judgements that are so often a source for court cases.

In order to be implemented properly the procedure, nevertheless, needs to be validated and probably adapted to national conditions. Readers of this paper are invited to collaborate in this exercise.

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