1.2 CROP PRODUCTION POTENTIAL OF SOILS

INTRODUCTION

A crop's production potential is a function of the soil, its properties and climate. A so-called high-potential wheat soil in the Central/Western Free State may differ entirely from a high potential wheat soil in the Western Cape. In the first case wheat is produced primarily on stored soil moisture and in the second case produced mainly on rainfall during the growing season.

The determination of a realistic yield target for a crop on a specific soil or in specific climatic conditions is of crucial importance, because the target set serves as the basis for crop production planning. It is preferable to refer to ecotopes where an ecotope represents specific soil, crop and climate combinations.

CROP CHOICE

A yield potential can only be linked to a soil within a specific climatic region if a crop can be profitably produced on that soil. Consequently, yield potential is expressed in terms of tons per hectare or kilograms per hectare (ton ha^{-1} or kg ha^{-1}).

The production potential of a crop on a specific soil or ecotope is used as a planning guideline in crop production. The determination of the production potential should be done as accurately as possible since most inputs required are derived accordingly. An accurate guideline should enable the producer to optimise profits and/or reduce risks.

The requirement for any crop is that the producer must be able to produce it economically on a specific soil in a particular area. Usually there is a choice of alternative crops. Crop choice is mainly determined by general basic and theoretical principles.

The following principles, requirements and limitations should be duly considered before a crop is chosen since each crop has a specific requirement with regard to the following:

(i) **Climatic requirements and limitations**

- Minimum and maximum temperatures of the area
- Rainfall (amount and distribution)
- Prevalence of wind erosion
- Potential hail damage
- Length of growing season

(ii) **Biological requirements**
- Drought tolerance of the crop
- Crop adaptability to the area

(iii) **Technical requirements**
- Effective soil depth
- Soil texture
- Soil fertility
- Other chemical soil factors

(iv) **Economic principles**
- Marketing prospects
- Gross margin and break-even yield
- Requirement and availability of capital-intensive specialist equipment
- Cash flow requirement of the producer

(v) **Other requirements and limitations**
- Crop rotation benefits and requirements of the crop
- Production losses due to local pests, fire and theft

PRODUCTION POTENTIAL OF A CROP IN A SPECIFIC SOIL-CLIMATE COMBINATION

If all the principles and requirements of a crop have been met, its production can be considered. However, the pertinent question is what the production potential of the crop is under the particular circumstances.

The production potential of a soil obviously only makes sense if it is specified according to the production of a crop. For example, a given soil can have a low potential for dryland maize production but a high potential for hay production from pasture crops under irrigation. For this reason, the potential of different crops must be determined separately.

Genetic potential

Genetic potential is that production which is only possible under ideal conditions. Actual production in practice is retricted or reduced by several factors, some of which are mentioned below.

Limiting factors

(i) **Soil**

Factors influencing the uptake, storage and availability of water include:
- depth due to a soil limiting layer;
- depth of root penetration (the deeper the better);

- texture (especially subsoil; clay holds more available water than sand);
- subsoil structure (a strongly developed macrostructure impairs root penetration);
- nature of the limiting layer (clay and soft plinthite can hold more water than hard rock or hard plinthite);
- soil surface condition (influences water infiltration);
- slope (run-off);
- pH and exchangeable acidity (excessive soil acidity impairs root development and function) – can be rectified;
- compacted layers (restrict root development) – can be rectified;
- effect of soil cultivation practices on the above.

(ii) **Climate**

- Rainfall (quantity, distribution and intensity), humidity, wind and temperature can be limiting (for plant growth and water evaporation from the soil).

(iii) **The farmer**

- The farmer's ability to apply and manage production resources in such a way as to maximise their utilisation..

These factors contribute to the definitions of "target yield, planned yield, optimum yield and maximum economic yield''. These terms all have one common denominator; they define a yield value lower than the theoretical potential, taking into account the limitations mentioned.

TARGET

When planning, the farmer and/or his adviser must ultimately decide on a yield target.

The following factors can play an important role in decision-making regarding the production potential of a crop on a specific soil:

(i) **Production history – practical** experience and knowledge
Medium to long-term yield records of lands should be considered as an important reference value when determining yield targets .

(ii) **Chemical and physical limitations**
Chemical limitations or (sub)soil acidity and soil compaction result in the physicochemical potential of a soil not being utilised. Beware of setting unrealistic targets in this regard.

(iii) **Target yields for different lands (soils)**
Fields with different soil characteristics should be differentiated.

(iv) **Research results**
Evaluate applicable research results of experiments on similar soils in the area.

(v) **Price ratios and costs**
Crop planning must take current cost price ratios into account in order to minimize risk.

Planning for excessively high yields creates unrealistic expectations among producers and stimulates unnecessary production inputs that increase risk during a dry cycle. Risks increase considerably when these targets are not reached during a dry cycle.

Target yields are no guarantee for an estimated, predicted yield. Rather, they indicate yield probability under given circumstances; or the average yield that could be realised in the medium-term.

GUIDELINES AND RESOURCES FOR DETERMINING A TARGET YIELD

As can be deduced from the above, determining a target yield for a specific crop-soil-climate combination is influenced by many factors. However, over the years generalised and simplified procedures and guidelines for general or personal use have been developed by various institutions. All the procedures are founded, to a greater or lesser extent, on the conversion of the estimated or the measured preplant plant-available profile water status plus the expected effective growing season rainfall relative to a crop target yield.

Crop growth models

The accuracy of target yield estimates is determined by the availability of the different crop growth, soil and climate variables. The most accurate estimates are done by computerised crop growth models that require a comprehensive register of input information. Examples of locally developed models are given in Table 1.2.1. A variety of international models are also available, some of which have already been adapted for local use by different institutions.

Long-term crop yields

Long-term historical crop yield data adapted for improved cultivars, fertilization and other cropping practices, can also be used to determine a crop target yield.

Empirical formulae

Among the most noted locally developed formulae for estimating crop target yields, particularly for maize, are those of Crafford and Nott (1970) and Möhr (1977).

Table 1.2.1. Locally developed crop growth models

Model	Institution
ACRU	Department of Agricultural Engineering, University of KwaZulu-Natal, Pietermaritzburg
CANE-GRO	SA Sugar Association, Mt Edgecombe
PUTU and SWAMP	Department of Soil, Crop and Climate Sciences, University of the Free State, Bloemfontein
SWB	Department of Plant Production and Soil Science, University of Pretoria, Pretoria

When these procedures are used, they need to be adapted for the higher crop index of improved cultivars.

The following water production function was proposed by Bennie et al. (1988) for the calculation of a generalised crop target yield for a number of crops.

$$Y_a = [Y_m - (Y_m \bullet (1-(T_a/T_m)))] \bullet CI$$

where Y_a = estimated grain yield (kg ha^{-1})
Y_m = maximum total biomass (kg ha^{-1})
T_a = water available for transpiration (mm)
T_m = maximum water used to produce Y_m (mm)
CI = crop index

Only T_a must be estimated. The remaining variables, for different crops, are given in Table 1.2.2. The formula looks complicated but when presented in a spreadsheet programme, with brackets in the right places, the calculations are simple .

Estimation of T_a: The quantity of water available for plant production (T_a, mm) equals the preplant stored plant-available water (W, mm) in the soil profile plus the effective rainfall during the growing season.

$$T_a = W + a \bullet R_g$$

where a = rainfall effectivity (Table 1.2.2)
R_g = expected or real growing season rainfall (mm)

To calculate W, the wetting depth (z, metre), during or before planting, and the average silt plus clay content of the soil profile to a maximum depth of 1.8 m, are required. In water table soils the depth of the water table (WTz, m) is also required.

Soils without water table: $T_a = PBW \cdot z + a \cdot R_g$

Soils with water table: $T_a = PBW \cdot z + a \cdot R_g + b \cdot (2\text{-}WTz)$

where PBW = the plant-available water (mm m^{-1}) for the corresponding silt plus clay content (Table 1.7.1) in Chapter 1.7 (mm)

b = Water table contribution factor
Silt + clay % < 5% = 250
> 5% = 180

Table 1.2.2. Variables for use in water production function for different crops

Crop	Y_m	T_m	CI*	a
	(kg ha^{-1})	(mm)		
Potatoes	62 400	564	0.90	0.48
Dry beans	8 400	494	0.40	0.75
Groundnuts (seedpods)	14 450	597	0.30	0.63
Cotton	18 600	900	0.35	0.65
Wheat	14 000	543	0.40	0.74
Maize	25 300	684	0.50	0.60
Soya beans	14 280	603	0.35	0.65
Sorghum	17 150	439	0.35	0.60
Sunflower	8 500	456	0.45	0.60
Natural grassland:				
Good covering	8 000	840	0.90	0.95
Poor covering	8 000	733	0.90	0.80

* *CI – adapt to chosen cultivar and for moisture stress.*

SUMMARY

The production potential of a soil is determined by soil specific requirements, for example depth, climatological limitations, biological requirements or the crop to be grown and the application of economic parameters of cultivation. Soil characteristics should therefore not be viewed in isolation and must not be confused with the so-called “genetic potential of a certain crop.

It can be concluded that the actual crop yield achieved is influenced by many factors. In Southern Africa, with its prevailing semi-arid climate, the amount and the distribution of rainfall during the growing season are perhaps the biggest contributing factors that determine crop yield. These factors are also the most difficult to offset when determining the potential

crop yield target.

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