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Actual landuse advice in marginal areas of SE-Kenya by atmosphere-ocean-teleconnection

Aktuelle Anbauempfehlungen in den semiariden Gebieten SE-Kenyas mit Hilfe einer Echtzeitvorhersage (El Niño Southern Oscillation)

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1 Introduction

FARMER (1988) and OGALLO (1988) have shown, that the El Niño Southern Oscillation Phenomenon (=ENSO) is influencing the Trade Wind System and the performance of the second (=short) rainy season in the coastal areas and the adjacent hinterlands of Eastern Africa. Usually rainfall is higher and more reliable when the air pressure difference in the Southern Pacific Ocean between the island of Tahiti and Darwin/Australia is below 1.054 hectopascal as WILLEMS (1989) found out. This happens in about 25% of all short rainy seasons. However, about one third of the short rainy seasons in most of the semiarid drylands of SE-Kenya can be classified as Anti-ENSO due to short durations, low amounts and high variabilities of the rains compared with normal/mean conditions.

These world wide atmospheric dynamics are also touching the southeastern and eastern parts of the new Makueni District (=eastern parts of the former Machakos District), in particular the agroecological zones L/LM 5 and L/LM 6 (acc. to JAETZOLD and SCHMIDT, 1983). For several years farmers from the overpopulated central parts of the Machakos and Kitui Districts are migrating into the semiarid Kiboko-Makindu-Kibwezi area (see: HORNETZ, 1988) where crop cultivation is limited by marginal rainfall conditions particularly in Anti-ENSO seasons as rainfall analysis of the last 60 years have revealed (WILLEMS, 1989; FRENKEN, 1991; see also Tab. 1).

Traditionally farmers use to plant high yielding varieties of maize (like Katumani Comp. B or Makueni DLC) and beans (like Mwezi moja – *Phaseolus vulgaris*

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GLP 10004 –) as main food crops. Particularly the last seasons with predominantly Anti-ENSO rainfall conditions showed that they run a high risk of crop failures for those crops which are not or less adapted to the ecological conditions of the drylands. On the other side the recently introduced drought resistant Tepary bean (*Phaseolus acutifolius*) with about 60 days till full maturity (see: HORNETZ, 1990) performed very well at the same time in off- as well as on-farm-experiments.

The establishment of a new forecasting system for ENSO, Anti-ENSO or Normal rainfall conditions before the onset of the rains (WILLEMS, 1989) could enable farmers to make precise decisions about cropping patterns best adapted to the predicted rainfall conditions; thus helping them to stabilize food production and — by successfully covering the soil with crops – protect the soils against the impact of heavy rain showers, runoff and soil erosion.

2 Materials and Methods

WILLEMS (1989) used the stochastic rainfall model of STERN (1980) in order to describe daily rainfall in SE-Kenya. In a first step of this model, the prohability of a wet day is estimated using instationary markov chains, and in a second step, the rainfall amount on wet days is described using the Gamma distribution. The analysed period is divided into three subgroups, according to the El Niño Southern Oscillation Phenomenon (CADET, 1985). Using the Southern Oscillation Index (SOI), threshold figures of SOI lower than 1.054 for ENSO- and SOI greater than 2.33 for Anti-ENSO-years were calculated and then used as discriminating criteria for each individual short rainy season. As could be shown, this procedure led to a statistically significant improvement of the rainfall simulation model (seel also: WILLEMS and SYMADER, in press).

FRENKEN (1991) used both the empirical and the simulated rainfall data on a daily basis for Makindu and Kibwezi (data from 1926 till 1985) in her study on the optimization of landuse patterns in SE-Kenya by means of a new system of forecasting yield potentials for definded crops under ENSO, Anti-ENSO and Normal rainfall conditions. Agroecological conditions and yield potentials (HORNETZ, 1988) were estimated according to the computations of the simulation model MARCROP (=MARginal CROPping: HORNETZ, 1988; HORNETZ and WILLEMS, 1989, unpublished).

The ecophysiological and phenological parameters of the model (like crop water requirements, stress patterns, availability of soil moisture, hydrature periods) were obtained in laboratory (climatological laboratory, University of Trier, Germany) as well as in field experiments (KARI/National Range Research Centre Kiboko, SE-Kenya) in 1985 and 1988, respectively (description see: HORNETZ, 1988, 1991). In 1990 the experiments were extended to several farmers in the Kiboko-Makindu area; thus giving additional agronomical informations and data. The soils of the experimental sites are representative for large areas of the drylands of SE-Kenya (acri-rhodic

Ferralsols, Luvisols), discribed by MICHIEKA and VAN DER POUW (1977) and HORNETZ (1991).

Special reference was dedicated to 2 short-cycle bean varieties with a 60 days'vegetation period: Tepary beans (*Phaseolus actifolius* A. Gray), a drought resistant minor pulse orginating from the semideserts of SW-North America and NW-Mexico, with a high protein content of about 25% (NABHAN et al., 1980, 74-75), and Mwezi moja beans (*Phaseolus vulgaris,* GLP 1004), a highyielding Kenyan variety which is less adapted to hot and dry places due to limited mechanisms of drought resistance (HORNETZ, 1990).

3 Results and Discussion

3.1 Rainfall analysis and yield simulation

The rainfall simulations of WILLEMS (1989) showed a remarkable increase of rainy days and rainfall amounts for ENSO seasons in the coastal areas and coastal hinterlands of Kenya, as was also found by OGALLO (1988). This can be observed particularly in November, the peak month of the short rains, with an increase of e.g. 35% at Kibwezi (Tab. 1).

Tab. 1: Mean monthly rainfall (in mm) during the short rainy season in SE-Kenya under different types of world wide atmosphere-ocean conditions.

	ENSO			Anti-ENSO			Normal		
	Oct.	Nov.	Dec.	Oct.	Nov.	Dec.	Oct.	Nov.	Dec.
Makindu	34	230	113	15	118	94	37	223	99
Kibwezi	34	255	120	13	153	136	30	185	131

(Dwa Plant.)

In that case the growing conditions within the agroecological zone (AEZ) LM 5, the millet zone (JAETZOLD/SCHMIDT, 1983), are improved so much, that farmers are able to cultivate high yielding maize varieties like Katumani Comp. B which generally performs with good results in AEZ LM/UM 4.

Anti-ENSO seasons have a significant decrease in rainfall amounts for a longer time (October and November) and much further inland resulting by as much as 43% below the mean in October and 20% in November at Kibwezi, 60% and 45% at Makindu, respectively (Tab. 1).

FRENKEN (1991) has compared simulated and real rainfall data with chances for cropping of Mwezi moja and Tepary beans using the experimental data of HORNETZ (1988, 1990, 1991). It was found that crop yield potentials for both crops vary from season to season, significantly correlated with ENSO, Anti-ENSO and Normal rainfall conditions[1]. In Anti-ENSO seasons the stress adapted Tepary beans outyielded the less adapted Mwezi moja as Tab. 2 and Fig. 1 are indicating:

Tab. 2: Yield expectations according to the simulation computations with MARCROP (FRENKEN, 1991) for ENSO (E), Anti-ENSO (A) and Normal years (N).

	Crop failures[a) (in % of all seasons)						Good optimum[b) yield expectations (in % of all seasons)					
Site	Tepary beans			Mwezi moja			Tepary beans			Mwezi moja		
	E	AE	N	E	AE	N	E	AE	N	E	AE	N
Makindu	0	6	0	17	59	56	58	18	33	8	6	12
Kibwezi	0	6	0	25	52	30	42	30	39	18	0	12

[a) „Crop failure" means: Yield expectations less than 20% of optimum (acc. to JAETZOLD and SCHMIDT, 1983).

[b) Optimum yields for Tepary beans means: about 1000-1100 kg/ha acc. to Tab. 3.

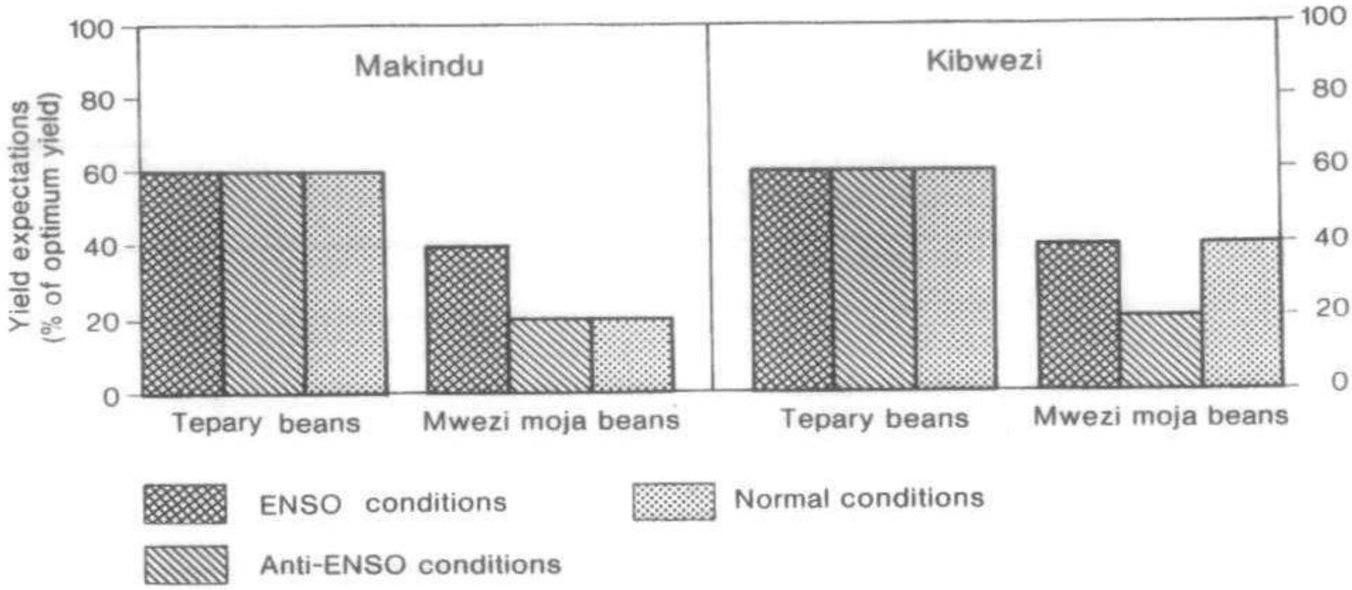

Fig. 1

Whereas there is only a failure risk of 6% (1 season out of 17) for Tepary cultivation in Anti-ENSO years at both sites, Mwezi moja fails in at least 1 out of 2 Anti-ENSO seasons (about 50-60% failure risks for Makindu and Kibwezi), the dominating agroecological pattern in 2 out of 3 seasons is 6[2], the failure type. Even with Normal

[1] About 33% of all short rainy seasons can be classified as Anti-ENSO situations, only about 25% as ENSO (WILLEMS, 1989, 70-71).

[2] Agroecological types/patterns (acc. to: HORNETZ, 1988)
  1 optimum (80-100% of optimum yield)
  2 suboptimum (60-80% of optimum yield)

and ENSO-conditions Mwezi moja is calculated to reach not more than marginal or poor yield potentials (=up to 40% of optimum with 67% prohability; Tepary beans reach up to 60% of optimum at both sites; see Fig. 1). In that case, particularly under ENSO conditions, the cultivation of high yielding varieties can be discussed because of 40% of the optimum for Mwezi moja means a production of about 800-100 kg of dry seeds per ha; Tepary beans with a better potential of 60% of the optimum would reach only about 600-700 kg/ha under the same conditions!

3.2 Off- and on-farm-experiments and calibration of the model

The short rains 1990/91 in the Kiboko-Makindu area are representing a typical Anti-ENSO situation:

Rainfall at NRRC Kiboko was 0 mm in October, 136 mm in November and 102 mm in December. The rains' onset dates were 8th and 9th of November (7.7 and 24.5 mm, respectively) and ended by 18th and 19th of December (followed by some weak postrains at 31th of December and 2nd of January which amounted to 5.9 and 0.8 mm, respectively). The on-farm-experiments near Kiboko/Makindu as well as the experiments at the old nursey of NRRC Kiboko started by the 10th of November. After about 60 days (begin of January 1991) the Tepary plots showed full maturity, the other crops at the farmer's fields were exposed to a prolonged period of water stress leading to high yield decreases (Maize Katumani Composite B-, local bean varieties etc.), total crop failures (e.g. Pigeon Peas) and emergency maturation (Sorghum K 369/Katumani). The yields of Tepary beans however were optimum compared to the results obtained by experimentation in the good to very good (distribution, amount of rainfall) long and short rains 1989 (Tab. 3).

The experimental data were used to calibrate the simulation model MARCROP. It was found out that soil moisture conditions were favouring Tepary bean cultivation in most of the analyzed seasons (1989-1991: agroecological type 1, optimum; see Fig. 2a).

Only the short rains 1991/92 were less favourable so that fair yields could be obtained in the off-farm-experiments (about 55% of the optimum; see Tab. 3). MARCROP calculated the average agroecological type 3.

Mwezi moja, however, got only enough rainfall during the short rains 1989/90 to produce a good crop. Other seasons could be classified below average (long rains 1989 and 1990) due to yield reducing dry spells during the most sensitive phenological phases of flowering and pod development. The short rains 1990/91 and 1991/92 were

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3 average (40-60% of optimum yield)
4+5 marginal (20-40% of optimum yield)
6 minimum-crop failure (< 20% of optimum yield)

too short for Mwezi moja, so that only minimum yield potentials could be calculated (agroecological type 6a; see Fig. 2b).

Tab. 3: Rainfall (in mm) and yields (in kg/ha) for Tepary beans in the Kiboko-Makindu area; field experimentation 1989-1991)

Site	Month	Long r. 1989 Rainf.	Long r. 1989 Yield	Short r. 1989 Rainf.	Short r. 1989 Yield	Short r. 1990 Rainf.	Short r. 1990 Yield	Short r. 1991 Rainf.	Short r. 1991 Yield
Old nursery,	Febr.	0							
NRRC	March	38							
Kiboko	April	167	1098						
(off-farm)	May	76							
	Oct.			114		0		1	
	Nov.			170		136		120	
	Dec.			106	1031	102	1036	76	587
	Jan.			86		8		0	
Muisuni	Oct.					0			
(on-farm)	Nov.					136			
	Dec.					102	1072		
	Jan.					8			

Planting Distance 40 x 40 cm; sole cropping (without manure)

These results coincide very well with the observations of the farmers in the testing area.

3.3 Conclusions

As a consequence of these results, an early warning could be given to farmers as early as August (WILLEMS, 1989) by the Kenya Meteorological Department, Nairobi (e.g. through the radio) if an Anti-ENSO condition for the second rainy season is expected. This normally happens when the difference in air pressure between Tahiti and Darwin/ Australia is above 2.33 hectopascal. Under these conditions they should save some maize for famine and provide themselves with seeds of less demanding crops resp. varieties like Tepary beans which are expected to perform successfully under less favourable rainfall conditions. If the air pressure difference is below 1.054 they should also be informed about the expected ENSO condition so that they take the chance to plant some high yielding crops resp. varieties (e.g. Katumani Composite B instead of Makueni DLC, or Mwezi moja beans instead of Tepary beans).

4 Summary

The major objective of this study is to present an agroecologically based system of forecasting yield potentials and cropping risks for definded crops in the semiarid drylands of SE-Kenya by means of atmosphere-ocean-teleconnection (El Niño Southern

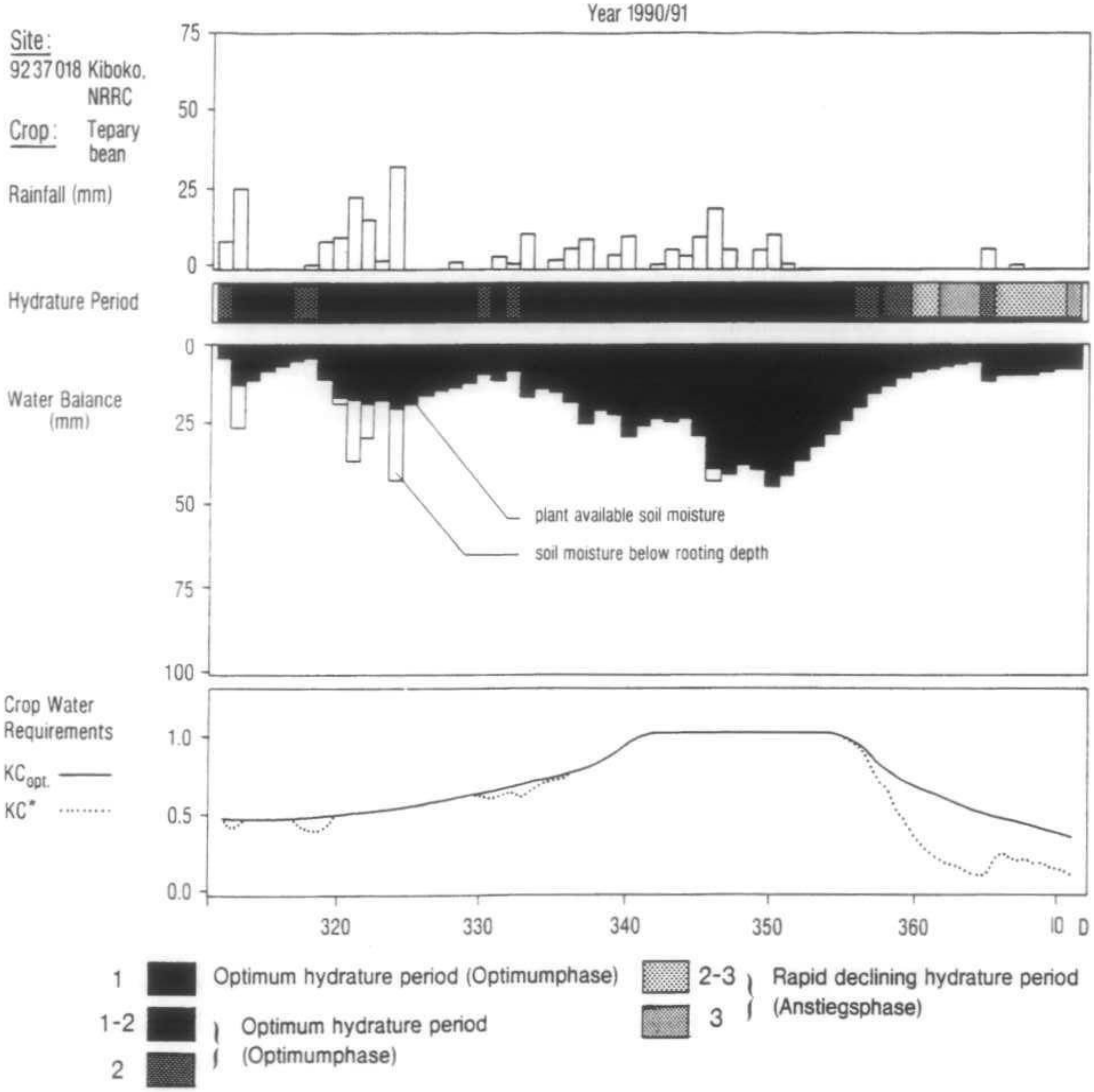

Fig. 2a: Hydrature periods (acc. to: KREEB, 1958; mod. by HORNETZ, 1988)

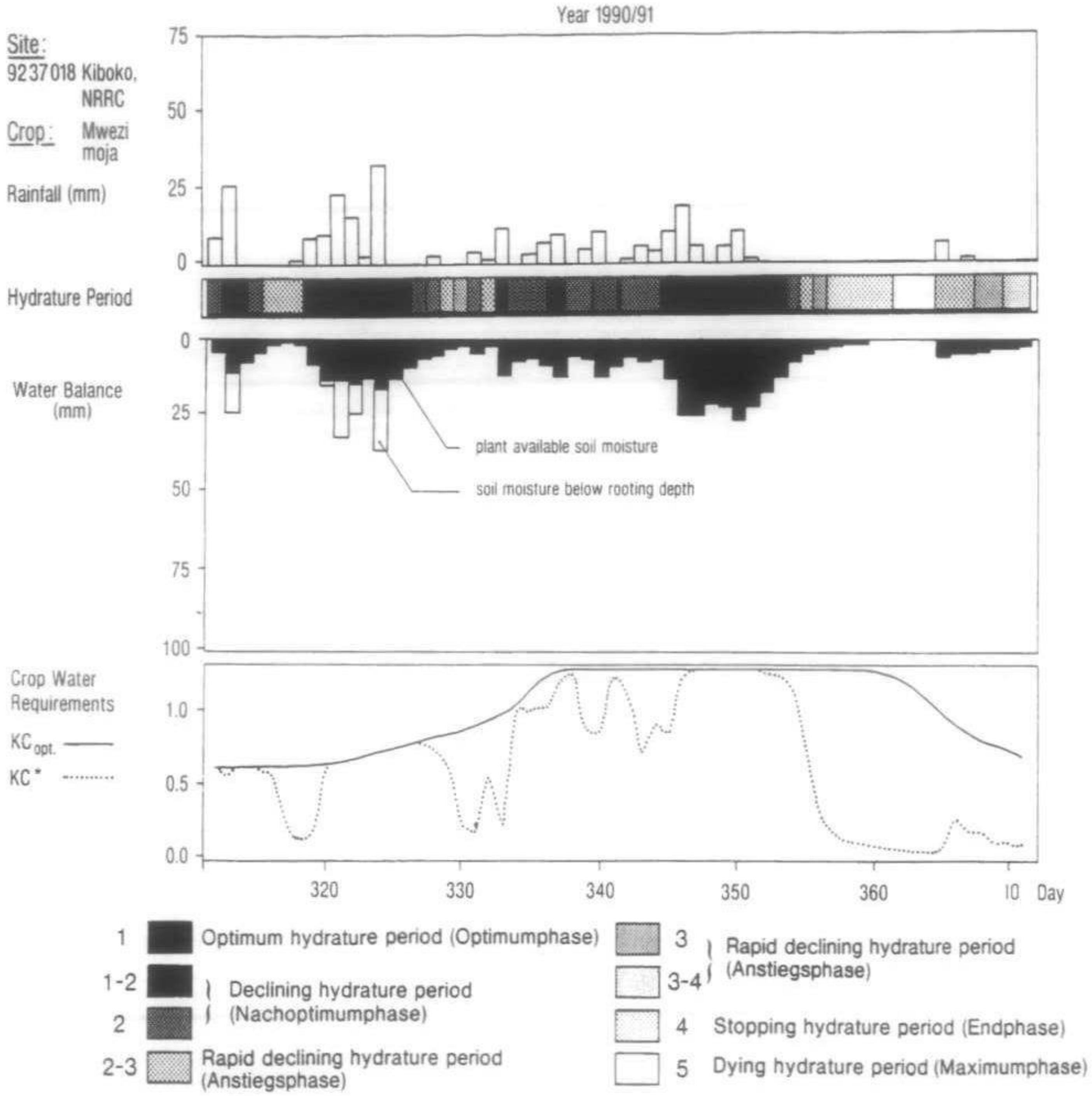

Fig. 2b: Hydrature periods (acc. to KREEB, 1958; mod. by: HORNETZ, 1988)

Oscillation Phenomenon = ENSO). Three distinct rainfall conditions during the short rains, i.e. ENSO, Anti-ENSO and Normal were identified from calculations with a rainfall simulation model. Under ENSO rainfall conditions, rainfall was found to be above normal while the reverse was found for the Anti-ENSO conditions. These results from the rainfall simulation model were then used to estimate yield potentials under the three rainfall conditions by means of an agroecological simulation model (MARCROP) that was calibrated on the results of laboratory (University of Trier, Germany) and field (off- as well as on-farm) experiments at and near KARI/NRRC Kiboko, Kenya. From this analysis, it was found that farmers should already be informed as early as in August (before the onset of the short rains) about the expected rainfall conditions so that they are able to decide on the selection of crops and crop varieties for cultivation early enough. Drought resistant, short-cycle Tepary beans (*Phaseolus acutifolius)* turned out to be the best suited for Anti-ENSO and Normal conditions when the cropping risk for high yielding but less adapted bean and maize varieties is too high (e.g.: 1 out of 2 seasons is failing for Mwezi moja beans — *Phaseolus vulgaris*, GLP 1004). However, in ENSO years soil moisture conditions are sufficient to bring up Mwezi moja beans and maize (Katumani Composite B).

Zusammenfassung

In der vorliegenden Studie wird versucht, Ertragspotentiale und -risiken definierter Kulturpflanzen in den Gebieten an der agronomischen Trockengrenze SE-Kenyas mit Hilfe eines Echtzeitmodells (El Niño Southern Oscillation, ENSO) auf agrorökologischer Basis vorherzusagen. Über ein Niederschlagssimulationsmodell werden 3 unterschiedliche Niederschlagsausprägungen (ENSO, Anti-ENSO, Normal) der 'Short rains'ausgewiesen: In ENSO-Regenzeiten liegt das Niederschlagsaufkommen an den untersuchten Klimastationen über, in Anti-ENSO-Regenzeiten unter den langjährigen Mittelwerten. Die Niederschlagsdaten werden anschließend in das über Feld (On- und Off-Farm: KARI/NRRC Kiboko, SE-Kenya) und Laborexperimente (Universität Trier) kalibrierte Ertragssimulationsmodell für marginale Kulturpflanzen MARCROP eingespeist und zusammen mit anderen klimatischen, pedologischen, streßphysiologischen, ertragsrelevanten und anbautechnischen Parametern verrechnet.

Die Analyse der Niederschlagsprägungen auf der Basis des 'Southern Oscilllation Indexes (SOI)'und der damit verbundenen Ertragspotentiale ergibt, daß man die betroffenen Kleinbauern bereits im August (ca. 2 Monate vor dem Einsetzen der 'Short rains') über die Entwicklung der bevorstehenden Regenzeit in Hinblick auf die zu erwartenden Erträge informieren kann. Dadurch sind sie in der Lage, frühzeitig Entscheidungen über die Auswahl geeigneter Kulturpflanzen (-varietäten) für den Anbau treffen zu können. Es zeigt sich, daß sich die kurzzyklischen, trocken- und hitzeadaptierten Tepary-Bohnen (*Phaseolus acutifolius*) am besten für Anti-ENSO- und Normal-Regenzeiten eignen, da das Ertragsrisiko für die weniger oder nichtangepaßten Hochertragsbohnen- und -maissorten zu hoch ist (z.B. ist für die kurzzyklische Mwezi Moja-Bohne — *Phaseolus vulgaris*, GLP 1004 — mit einem totalen Ertragsausfall in etwa 1 von 2 Anti-ENSO- und Normal-Regenzeiten zu rechnen). In (feuchteren) ENSO-Regenzeiten reichen die Bodenfeuchtebedingungen jedoch in der Regel aus, um solche Hochertragssorten (wie auch z.B. Mais Katumani Composite B) zur Ertragsreife zu bringen.

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