POTENTIAL CROP PRODUCTION
— illustrated by an example from West Africa

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Different ways of describing and modelling the process of primary production are compared, and the concept of potential crop production is elaborated.

Two mathematical models are suggested, converted into FORTRAN IV, and used for an estimation of potential productivity in Ghana.

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An analysis of the process of primary production may follow two different strategies. According to the one, the ecological, the interest is concentrated on the net primary production, i.e. the harvestable dry matter (Lieth, 1973). These analyses are always empirical and do normally only correlate the actual observed net primary production with different relevant environmental parameters. According to the other, the physiological strategy, the analysis includes a careful physiological investigation of models of the basic photosynthetic processes combined with a mathematical model describing the structure of the canopy. The aim is to combine these two strategies so that relevant environmental parameters are not correlated with actual observed plant production, but included in physiologically well established mathematical models describing gross primary production and respiration as a function of these parameters.

Numerous investigations have been made on the observed maximum crop productivity (Blackman, 1968, Niciporovic, 1968, Murphy, 1975, Loomis and Gerakis, 1975, Evans, 1975). Fewer investigations are dealing with the maximum possible productivity (Boysen-Jensen, 1932, Loomis and Williams, 1963, Cooper, 1975) and only a few are trying to delimitate the concept of potential crop production. In this paper, potential crop production will be described in accordance with the definition given by de Wit (1959) and Monteith (1965) as the net primary production in a vegetation not restrained by its canopy structure, possessing a closed crop surface (de Wit, 1959) and having a canopy structure with the lowest leaves barely producing above the compensation point (Monteith, 1965). The vegetation must not suffer from water shortage or lack of mineral ions and is only limited in its growth by radiation, temperature and carbondioxide.

MODELLING THE PRODUCTIVITY

When modeling the potential productivity, both the surrounding physical environment and the vegetation has to be described in accordance with the definition given. A general outline, showing the different types of models is given in fig. 1.

MODELS OF PLANT PRODUCTIVITY		VEGETATION	
		DYNAMIC	STATIC
PHYSICAL ENVIRONMENT	MANY CONSTRAINTS	SIMULATION OF ACTUAL PRODUCTION	ACTUAL PRODUCTIVITY
	FEW CONSTRAINTS	SIMULATION OF MAXIMUM PRODUCTION	POTENTIAL PRODUCTIVITY

Fig. 1. General outline, showing different ways of modelling the productivity. The models are divided according to their description of the surrounding physical environment and to their inclusion of the time factor in their simulation of the canopy structure.
Fig. 1. Produktionsmodeller, oversigt.

As seen, potential production is best described by a static model — where the vegetation is assumed to be invariable — and with only a few constraints from the surrounding physical environment. The environment is best described by only a few constraints (de Wit, 1959, Monteith, 1965) as the involvement of many (Paterson, 1956, Ryabchikov, 1968, Bazilevich et al., 1971, Lieth, 1973) will only simulate the actual production conditions. Likewise the vegetation is best assumed to be invariable through the growing season (Budyko, 1956, 1974, de Wit, 1959, 1965, Monteith, 1965, Duncan et al., 1967) as a growing vegetation, where the productivity is estimated at different stages of development is impossible to describe without an extensive application of empirical observations (de Wit, Brouwer and Penning de Vries, 1970, Monteith and Elston, 1971, Patefield and Austin, 1971). The empirical aspect makes the estimate approach a measurement of actual production conditions — not very logical when delimiting potential crop production.

The static models develop the productivity of the total canopy either from the light-photosynthesis relation of single leaves (de Wit, 1959, 1965, Monteith, 1965, Duncan et al., 1967) or from the carbondioxide profiles within the canopy (Budyko, 1956, 1974). Only de Wit (1959) and Monteith (1965) attempt to describe the optimum canopy structure: they both assume a closed crop surface and a canopy structure maintaining a positive net production even for the lowest leaves. Both elaborate the gross primary productivity of the canopy from the light-photosynthesis relation of single leaves; de Wit (1959) however assume a straight-line relation between light and photosynthesis, whereas Monteith (1965), using Gaastra's (1959) light-response curves, introduces a more realistic curvelinear relation between light and gross photosynthesis. Monteith's model will therefore in the following be used for an estimation of potential gross primary production.

The daily total potential gross primary production is in Monteith's model estimated to be a function of daily total radiation and daylength in a vegetation assumed to have an indefinite high leaf-area index and characterized by a transmission coefficient, a diffusion resistance, a photochemical resistance, and a s-factor describing the canopy structure. As the photochemical resistance differs greatly with plant species (Monteith, 1974), it is possible to express potential production for different crops by assigning the resistance-different values. A FORTRAN IV programme estimating potential gross production according to Monteith's model will have the following appearance:

```
      READ(5,1o1)X,Z
      FORMAT (1X,F5.1,2X,F4.1)
      Y=(X•22.0)/(14.0•7.20.0)
      A=(0.125•0.45•Y-0.05)/(0.125•0.45•Y•0.05)
      B=(0.125•0.45•0.1•Y-0.05)/(0.125•0.45•0.1•Y•0.05)
      IF(A.LE.0.0)C=(14.0/22.0)•((1•ABS(A))/SQRT(ABS(A)))•ATAN
     1(SQRT(ABS(A)))
      IF(A.LE.0.0)GO TO 45
      C=(7.0/22.0)•((1-A)/SQRT(A))•ALOG((1•SQRT(A))/(1-SQRT(A)))
   45 D=(14.0/22.0)•((1•ABS(B))/SQRT(ABS(B)))•ATAN(SQRT(ABS(B)))
      P=(12.0/0.125)•((1.0/0.45)•(1.0-C)•(1.0/0.45)•(1.0-D)
```

In this programme, the vegetation is characterized by a diffusion resistance on 0.125 m²hrg-1, a photochemical resistance on 0.05 cal g -1, a transmission coefficient on 0.1 and an s-factor on 0.55 (Zea Mays), and the daylength is supposed to be 720 minutes. A set of data-cards, each containing information on the daily radiation, was treated as prescribed by the programme. Through the READ statement daily total radiation was introduced as the variable X, converted into a measure on mid-day radiation intensity above the canopy, Y, and used in the following calculations. The variables A, B, C and D form part of the resulting total gross primary production, P, expressed in grammes dry-matter per square meter per day.

MODELS FOR ESTIMATING POTENTIAL NET PRODUCTION

Defining potential production at the net primary production level — that is gross primary production less respiration losses — makes a usable measure on respiration necessary. McCree (1970) assumes the rate of respiration proportional to the standing biomass and the rate of gross primary production. Improving this estimate McCree (1974) took the temperature dependence on the maintenance respiration in account. Recently, the maintenance respiration has been shown to depend on plant species (Penning de Vries, 1975); with knowledge in hand on this relationship for different crops McCree's (1974) formula is clearly revealed as the most accurate measure on respiration given. Regrettably, the estimate is not in accordance with Monteith's model: it will, when used on a static, invariable vegetation, lead to a contradiction between two assumptions: the standing crop assumed to be shifting, and the vegetation assumed to be invariable with an indefinitly high leaf-area index. The Monteith-McCree model will therefore not be used in an estimation of potential production proper, but shown as an example of a model, that through further work might be proven useful. Especially in a simulation of a crop during the growing season, the introduced part describing respiration will lead to a realistic decline in productivity (fig. 4). In FORTRAN the respiration part of the Monteith-McCree model is written as follows:

```
      U=0.25•P+((0.0209•SUME)•(0.044•(0.0019•Z)•(0.0010•Z•Z)))
      IF(U.GT.P) GO TO 47
      R=(U/P)•100.0
      GO TO 48
   47 R=100.0
   48 CONTINUE
      E=P-(P•R/100.0)
      SUME=SUME•E
```

The IF/GO statements ensure that the respiration does not exceed 100 percent — the lowest leaves are kept just above the compensation point. The standing crop is expressed by the variable SUME — the daily net primary production cumulated.

The problems mentioned above associated with the McCree-estimate have, however, made it necessary to express the respiration as a rather simple function of gross primary productivity and temperature (Chang, 1968 after Thomas and Hill, 1937); in FORTRAN:

```
      R=7.825•(1.145•Z)
      U=(P•R)/100.0
      SUME=SUME•SUME
```

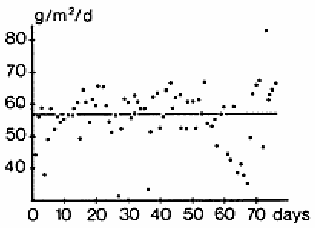
This estimate does not involve the standing biomass, it is in accordance with Monteith's model and can be used in an estimation of potential productivity. When the daily potential productivity is cumulated through the growing season, the Monteith-Chang model is however less realistic (fig. 4). In the model no consideration is given to the increasing respiration, and the resulting daily net primary production shows no sign of decline, as would be expected in a mature plant community. The model is, anyway, applicable to an estimation of potential production, when the time factor is not included, i.e. potential production in one day only. No development stage nor standing biomass has to be defined, as the estimate is independent of these variables; a measure like this will clearly be usable when mapping potential productivity.

Monteith-McCree Model: Simulation of potential growth
Monteith-Chang Model: Potential productivity

SIMULATING THE POTENTIAL GROWTH OF A CROP

An estimation of the potential crop production in West Africa made considerable amounts of meteorological information necessary: for the year 1974 data on daily solar radiation were taken from »Solar Radiation and Radiation Balance Data« (Leningrad, 1974). As regards temperature the problem was to gain information from exactly the same locations and dates as for radiation. This was possible through the combined use of »Monthly Climatic Data for the World« (W.M.O., Washington, 1974) and »Monthly Weather Report« (Ghana Meteorological Services Department, Accra, 1974). As data on both radiation and temperature for a number of stations in Ghana and Nigeria were available it was an easy task to compute potential production for these locations: the data were transcribed to datacards, read by an UNIVAC 1100 computer and treated as prescribed by the introduced FORTRAN IV programme. The resulting figures expressed potential crop production in grammes dry matter per square meter per day as a function of radiation, daylength and temperature only.

fig 2



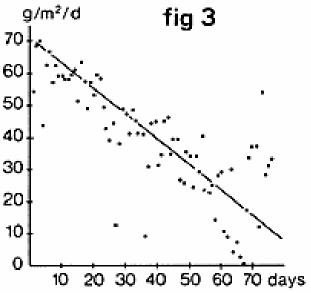


Fig. 2. Productivity simulated through the growing season, Monteith-Chang model. Zea mays, Ibadan 1.5.-15.6.1974. The productivity is seen to be constant through the growing season — not realistic, as both young and old populations will have smaller productivity (see text).

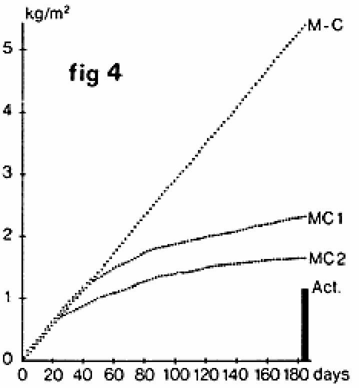
Fig. 2. Simuleret produktivitet gennem vækstperioden, Monteith-Chang model.

Fig. 3. Productivity simulated through the growing season, Monteith-McCree (1974) model. Zea mays, Ibadan 1.5.-15.6. 1974. The productivity is seen to be unrealistically high in the start of the growing season, but declines later in accordance with the actual conditions, where loss of leaves and increasing respiration is felt.

Fig. 3. Produktivitetens størrelse gennem vækstperioden, Monteith-McCree (1974) model.

In fig. 2 and 3 the two proposed models are compared. In fig. 2 the productivity is simulated through the growing season by the Monteith-McCree model, the productivity is seen to be constant through the growing season. Clearly this is not realistic: young crop populations will have a small productivity due to the insufficient leaf-area, while older crop populations will have declining productivity as a result of loss of leaves and wilting.

The Monteith-McCree model simulates this declining productivity in a realistic way: the productivity is seen to approach nil after 70 days (fig. 3). Unfortunately, this model does not simulate the evolving leaf-area; only the respiration part of the model is dynamic.



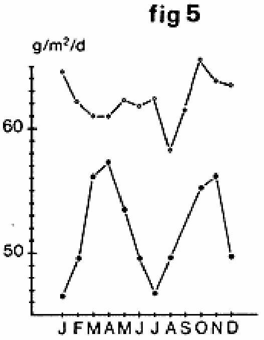


Fig. 4. Comparison of potential and actual production. Yam, Samaru 1.5.-1.11. 1974. Potential production, cumulated through the growing season, has been calculated for three combinations of models, M-C: Monteith-Chang. MC 1: Monteith-McCree (1970). MC 2: Monteith-McCree (1974). The actual production in grammes dry matter per square meter is shown as a black column (see text).

Fig. 4. Potentiel og aktuel produktion, yams. Tre potentialemodeller sammenlignet.

Fig. 5. Potential productivity through the year, calculated for the rainforest (Tafo, 6°15'N 0°28'W) and in the Sudan savanna (Navrongo O, 10°N53' 1°05'W). Sorghum, average 1965-74, Monteith-Chang model.

Fig. 5. Potentialets variation gennem året, Sorghum. Gennemsnit 1965-74.

A comparison of the two models with the actual production is given i fig. 4. Information on the growing season and maximum actual yields for the crops given were gained from Institute of Tropical Agriculture, Ibadan and various Danish agricultural advisers located in the area. The yield figures were converted into grammes dry-matter per square meter from information on the ratio between the harvestable part, wet weight/total biological dry-matter production (IITA, 1974, Kassam et al., 1975). The actual observed maximum production (black column) is compared to the simulated crop growth of the two models. Clearly, the Monteith-McCree models give the most realistic picture of the production possibilities. The Monteith-McCree model cumulates the daily production disregarding the different structure of the vegetation in a mature plant community. The almost constant respiration percentage proposed by the model is definitely not realistic throughout the whole growing season. In a comparison as the one shown, where the potential productivity is cumulated through the growing season, and where the model actually simulates the potential growth of a crop, the Monteith-McCree model is therefore preferable.

MAPPING THE POTENTIAL PRODUCTIVITY

Data on mean monthly solar radiation for the years 1965-74 (Solar Radiation and Radiation Balance Data, Leningrad) were combined with the corresponding

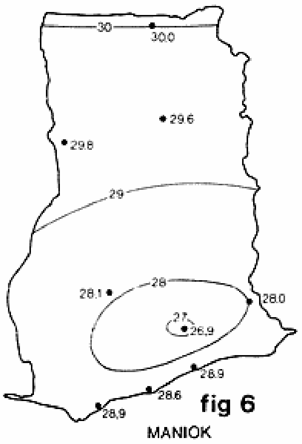


fig 6

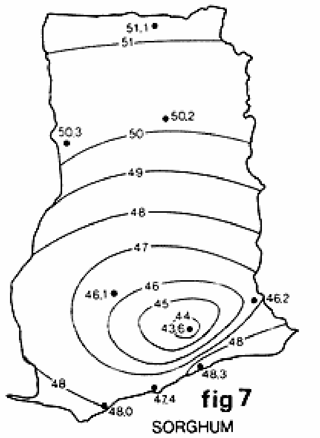


fig 7

Fig. 6. Potential productivity, Ghana. Manioc, grammes dry matter per m² per day, annual average 1965-74. Monteith-Chang model.

Fig. 6. Potentiel produktivitet, Ghana. Maniok, gram tørstof pr. m² pr. dag. Årsgennemsnit 1965-74.

Fig. 7. Potential productivity, Ghana. Sorghum, grammes dry matter per m² per day, annual average 1965-74. Monteith-Chang model.

Fig. 7. Potentiel produktivitet, Ghana. Sorghum, gram tørstof pr. m² pr. dag. Årsgennemsnit 1965-74.

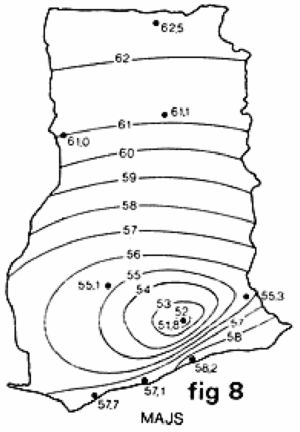


fig 8

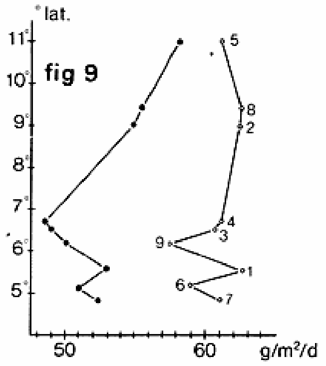


fig 9

Fig. 8. Potential productivity, Ghana. Zea mays, grammes dry matter per m² per day, annual average, 1965-74. Monteith-Chang model.

Fig. 8. Potentiel produktivitet, Ghana. Majs, gram tørstof pr. m² pr. dag. Årsgennemsnit 1965-74.

Fig. 9. Potential productivity as a function of latitude, Ghana, average 1965-74. Zea mays, Monteith-Chang model. Stations 1: Accra (5°36'), 2: Bole (9°01'), 3: Ho (6°36'), 4: Kumasi (6°43'), 5: Navrongo (10°53'), 6: Saltpond (5°12'), 7: Takoradi (4°53'), 8: Tamale (9°25'), 9: Tafo (6°25').

Fig. 9. Relationen mellem potentiel produktion, majs og breddegrad, Ghana, gennemsnit 1965-74.

monthly temperature data for the same locations and dates (Monthly Climatic Data of the World, W.M.O., Monthly Weather Report, Ghana Meteorological Services Department, Accra). By the use of the Monteith-Chang model these radiations and temperature data were converted into figures expressing potential daily production as monthly mean. The Monteith-Chang model was chosen, as the purpose was to gain information on the productivity only; a definition of development stage and standing biomass would only complicate the compilation. The carbondioxide factor was included through the diffusion resistance. Assigning this variable, different values made it possible to estimate the potential productivity for different crop types, according to their carbondioxide diffusion resistance (Monteith, 1974). The daily potential production was in this way estimated as a monthly mean for three crop types on nine locations in Ghana through the years 1965-74 (fig. 6, 7 and 8).

POTENTIAL PRODUCTION IN GHANA

The potential productivity has been compiled through the year for a station situated in the rain forest and a station situated in the Sudan savanna (fig. 5). In the rain forest, the potential shows great variation through the year with two distinct maxima in the dry months April and November. The potential productivity only varies little through the year in the Sudan savanna — only in August is the declining radiation input felt in Navrongo.

An illustration of the geographical distribution of the potential productivity for three crop types is given in fig. 6, 7 and 8. The highest figures are reached by Zea mays and Sorghum, both C4-plants with extremely effective photosynthetic processes. The potential is lowest in the rain forest around Tamale; the cloud cover is dense and the radiation intensity very low. From the rain forest the potential increases towards the coastal savanna in the south and toward the Sudan savanna in the north, mainly caused by an increasing radiation input.

I fig. 9 this gradient of productivity is shown for April and August; for the different meteorological stations the potential productivity is shown as a function of latitude. The potential is seen to be lowest in the cloudy rain forest around 6°N. In August the productivity increases very strongly with latitude — the cloudy rainy season is less felt in the northern part of Ghana. In April the distribution of radiation is rather uniform, and no great difference is observed in the extreme North — the influence of the high Ghana. Actually, a fall in the potential productivity is observed in the extreme north — the influence of the high temperatures of the dry season is felt. In April the optimum area for maize production can therefore be located at the 9° northern latitude; the potential gross production is very high, and the respiration is not yet influenced by the extreme temperatures found at higher latitudes.

The production potential of manioc (Manihot utilissima) is very uniformly distributed (fig. 6). The general pattern resembles that of maize (Zea mays) but the shown differences are too small to justify any conclusions.

The geographical distribution of the potential productivity of millet (Sorghum Sp.) has been shown for each month through the year (fig. 10). From the cloudy rain forest around 6°N, the potential productivity increases with latitude. The months March, April and May are so hot, that a decline in productivity — caused by the increased respiration — must to be expected north of 9°N.

CONCLUSION

Elaborating the concept of potential production two mathematical models have been introduced, converted into FORTRAN IV and used in a practical estimation of potential production. Maps have been constructed showing the geographical distribution of potential productivity in Ghana as a function of radiation and temperature. Considering these constraints only, the optimum area for the growing of Zea mays and Sorghum was shown to be located at 9°N.

RESUME

Forskellige former for analyse af plantevækst og tørstofproduktion omtales, og begrebet potentiel planteproduktion introduceres. Modelmæssigt beskrives potentiel planteproduktion bedst ved kun at inddrage få miljøbeskrivende parametre — stråling og temperatur — da anvendelsen af flere blot vil beskrive de aktuelle forhold. Ligeledes beskrives vegetationen bedst statisk; en dynamisk model med en variabel vegetationsbeskrivelse forsøger ikke at afgrænse en produktionsmæssig optimal vegetationsstruktur — produktionsestimatet er helt afhængig af det simulerede udviklingstrin.

En statisk model — omsat til FORTRAN IV — introduceres til bestemmelse af potentiel bruttoproduktion; kombineret med to forskellige respirationsestimater fås to modeller til bestemmelse af potentiel nettoproduktion. Det vises, at modellerne er velegnede til henholdsvis simulering af potentiel vækst samt bestemmelse af potentiel produktivitet. Begge anvendes praktisk, dels ved en sammenligning med aktuel produktion i Nigeria (fig. 4), dels ved en afgrænsning af den geografiske fordeling af potentiel produktivitet i Ghana (fig. 6, 7, 8 og 10).

For Ghanas vedkommende påvises en nord-sydgående potentialegradient (fig. 9); fra regnskovszonen øges potentialet med breddegraden og når et maximum omkring 9° nordlig bredde. De høje temperaturer nord herfor bevirker så stor respiration, at nettoproduktionen mindskes.

REFERENCES

Bazilevich, N.I., L.E. Rodin and N.N. Rozov (1971): Geographical Aspects of Biological Productivity, Sov. Geogr. Rev. Transl. May, p. 292-315.

Blackman, G.E. (1968): The Application of the Concepts of Growth Analysis to the Assessment of Productivity. Functioning of Terrestrial Ecosystems at the Primary Production Level. Proceeding of the Copenhagen Symposium 1965. Ed. by F.E. Eckardt, Natural Ressources Research 5. UNESCO; Paris.

Boysen-Jensen, P. (1932): Die Stoffproduktion der Pflanzen, Jena.

Budyko, M.I. (1956): Teplovi Balans Zemnoi Poverkhnosti Giderometeozidat, Leningrad, Heat Balance of the Earth Surface, translated by N.A. Stepanova. U.S. Weather Bur., Washington JD.C., 1958. MGA 8.5-20, 138-286.

Budyko, M.I. (1974): Climate and Life. International Geophysics Series Vol. 18. Academic Press, New York and London.

Chang, Jen-hu (1968): The Agricultural Potential of the Humid Tropics, Geogr. Rev. Vol. 58, p. 333-61.

Cooper, J.P. (1975): Control of Photosynthetic Production in Terristrial Systems. In: Cooper, J.P.: Photosynthesis and Productivity in Different Environments. International Biological Programme, Vol. Cambridge University Press, Cambridge.

Duncan, W.G., A.S. Loomis, W.A. Williams and R. Hanau (1967): A Model for Simulating Photosynthesis in Plant Communities. Hilgardia, 38: 181-205.

Evans, L.T. (1975): The Physiological Basis of Crop Yield. In Evans, L.T.: Crop Physiology: Some Case Histories.

Gaastra, P. (1959): Photosynthesis of Crop Plants as Influenced by Light, Carbon Dioxide, Temperature and Stomatal Diffusion Resistance. Mededeling, Landb. Hogesch., Wageningen, 59, p. 1-68.

IITA Annual Report (1974): International Institute of Tropical Agriculture, PMB 5320, Ibadan, Nigeria.

Kassam, A.H., J. Kowal, M. Dagg and M.N. Harrison (1975): Maize in West Africa: and its Potential in the Savanna Areas. World Crops, March/April (1975). Samaru Research Bulletin 250. Institute for Agricultural Research, Samaru. Ahmadu Bello University, PMB, 1044, Zaria, Nigeria.

Lieth, H. (1973): Primary Production: Terrestrial Ecosystems. Human Ecology, Vol. 1, No. 4, New York.

Loomis, R.S. and P.A. Gerakis (1975) Productivity of Agricultural Ecosystems. In: Cooper, J.P.: Photosynthesis and Productivity in Different Environments. International Biological Programme, Vol. 3. Cambridge University Press. Cambridge.

Loomis, R.S., W.A. Williams and W.G. Duncan (1967): Community Architecture and the Productivity of Terrestrial Plant Communities. In: San Pietro F.A. Greer and T.J. Army: Harvesting the Sun, Academic Press, New York and London.

McCree, K.J. (1970): En Equation for the Rate of Respiration of White Clover Plants Grown under Controlled Conditions. Prediction and Measurements of Photosynthetic Productivity. Proceedings of the IBP/PP Technical Meeting, Trebon 1969. Wageningen 1970. P. 215-220.

McCree, K.J. (1974): Equations for the Rate of Dark Respiration of White Clover and Grain Sorghum as Functions of Dry Weight. Photosynthetic Rate and Temperature. Crop Sci., Vol. 14, p. 509-515.

Monteith, J.L. (1965): Light Distribution and Photosynthesis in Field Crops, Ann. of Bot., NS., Vol. 29, p. 17-37.

Monteith, J.L. (1972): Solar Radiation and Productivity in Tropical Ecosystems, Journ. of appl. Ecology, Vol. 9, 3, p. 747-766.

Monteith, J.L. and J.F. Elston (1971): Microclimatology and Crop Production. In: Wareing, P.F. and J.P. Cooper: Potential Crop Production. Heinemann Eductional Books.

Monthly Climatic Data of the World (1965-74): US Department of Commerce. National Oceanic and Atmosperic Administration, Environmental Data Service. Sponsored by World Meteorological Organization.

Monthly Weather Report (1965-69): Ghana Meteorological Services Department. Ghana Meteorological Srvice Headquarters. P.O. Box 87, Legon, Accra.

Murphy, P.G. (1975): Net Primary Productivity in Tropical Terrestrial Ecosystems. In: Lieth, H. and R.H. Whittaker:

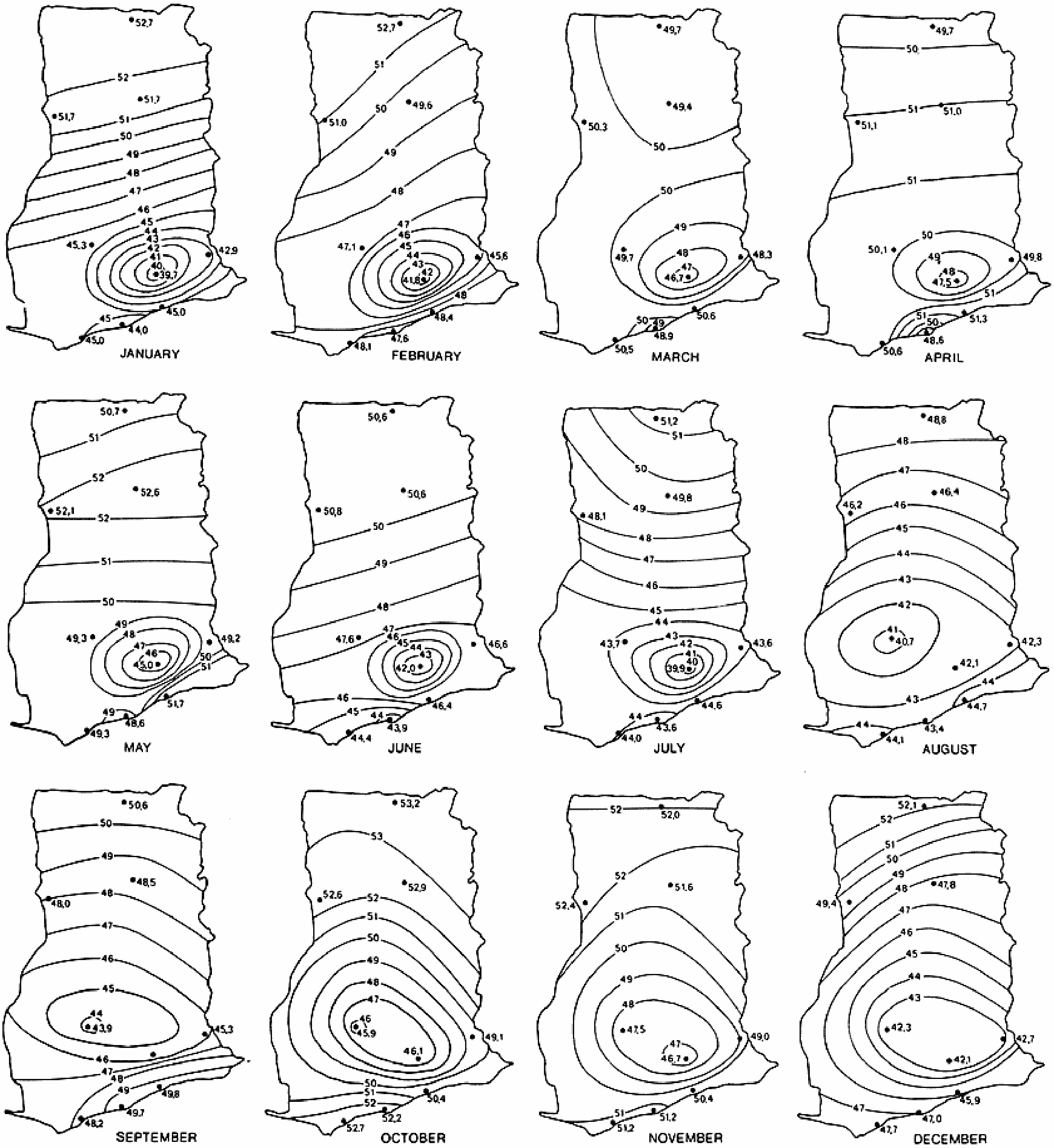


Fig. 10. Potential productivity, Ghana. Sorghum, grammes dry matter per m² per day, monthly average 1965-74. Monteith-Chang model.

Fig. 10. Potential produktion, Ghana. Sorghum, gram tørstof pr. m² pr. dag. Gennemsnit 1965-74.

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REFERENCES

Bazilevich, N.I., L.E. Rodin and N.N. Rozov (1971): Geographical Aspects of Biological Productivity, Sov. Geogr. Rev. Transl. May, p. 292-315.

Blackman, G.E. (1968): The Application of the Concepts of Growth Analysis to the Assessment of Productivity. Functioning of Terrestrial Ecosystems at the Primary Production Level. Proceeding of the Copenhagen Symposium 1965. Ed. by F.E. Eckardt, Natural Ressources Research 5. UNESCO; Paris.

Boysen-Jensen, P. (1932): Die Stoffproduktion der Pflanzen, Jena.

Budyko, M.I. (1956): Teplovi Balans Zemnoi Poverkhnosti Giderometeozidat, Leningrad, Heat Balance of the Earth Surface, translated by N.A. Stepanova. U.S. Weather Bur., Washington JD.C., 1958. MGA 8.5-20, 138-286.

Budyko, M.I. (1974): Climate and Life. International Geophysics Series Vol. 18. Academic Press, New York and London.

Chang, Jen-hu (1968): The Agricultural Potential of the Humid Tropics, Geogr. Rev. Vol. 58, p. 333-61.

Cooper, J.P. (1975): Control of Photosynthetic Production in Terristrial Systems. In: Cooper, J.P.: Photosynthesis and Productivity in Different Environments. International Biological Programme, Vol. Cambridge University Press, Cambridge.

Duncan, W.G., A.S. Loomis, W.A. Williams and R. Hanau (1967): A Model for Simulating Photosynthesis in Plant Communities. Hilgardia, 38: 181-205.

Evans, L.T. (1975): The Physiological Basis of Crop Yield. In Evans, L.T.: Crop Physiology: Some Case Histories.

Gaastra, P. (1959): Photosynthesis of Crop Plants as Influenced by Light, Carbon Dioxide, Temperature and Stomatal Diffusion Resistance. Mededeling, Landb. Hogesch., Wageningen, 59, p. 1-68.

IITA Annual Report (1974): International Institute of Tropical Agriculture, PMB 5320, Ibadan, Nigeria.

Kassam, A.H., J. Kowal, M. Dagg and M.N. Harrison (1975): Maize in West Africa: and its Potential in the Savanna Areas. World Crops, March/April (1975). Samaru Research Bulletin 250. Institute for Agricultural Research, Samaru. Ahmadu Bello University, PMB, 1044, Zaria, Nigeria.

Lieth, H. (1973): Primary Production: Terrestrial Ecosystems. Human Ecology, Vol. 1, No. 4, New York.

Loomis, R.S. and P.A. Gerakis (1975) Productivity of Agricultural Ecosystems. In: Cooper, J.P.: Photosynthesis and Productivity in Different Environments. International Biological Programme, Vol. 3. Cambridge University Press. Cambridge.

Loomis, R.S., W.A. Williams and W.G. Duncan (1967): Community Architecture and the Productivity of Terrestrial Plant Communities. In: San Pietro F.A. Greer and T.J. Army: Harvesting the Sun, Academic Press, New York and London.

McCree, K.J. (1970): En Equation for the Rate of Respiration of White Clover Plants Grown under Controlled Conditions. Prediction and Measurements of Photosynthetic Productivity. Proceedings of the IBP/PP Technical Meeting, Trebon 1969. Wageningen 1970. P. 215-220.

McCree, K.J. (1974): Equations for the Rate of Dark Respiration of White Clover and Grain Sorghum as Functions of Dry Weight. Photosynthetic Rate and Temperature. Crop Sci., Vol. 14, p. 509-515.

Monteith, J.L. (1965): Light Distribution and Photosynthesis in Field Crops, Ann. of Bot., NS., Vol. 29, p. 17-37.

Monteith, J.L. (1972): Solar Radiation and Productivity in Tropical Ecosystems, Journ. of appl. Ecology, Vol. 9, 3, p. 747-766.

Monteith, J.L. and J.F. Elston (1971): Microclimatology and Crop Production. In: Wareing, P.F. and J.P. Cooper: Potential Crop Production. Heinemann Eductional Books.

Monthly Climatic Data of the World (1965-74): US Department of Commerce. National Oceanic and Atmosperic Administration, Environmental Data Service. Sponsored by World Meteorological Organization.

Monthly Weather Report (1965-69): Ghana Meteorological Services Department. Ghana Meteorological Srvice Headquarters. P.O. Box 87, Legon, Accra.

Murphy, P.G. (1975): Net Primary Productivity in Tropical Terrestrial Ecosystems. In: Lieth, H. and R.H. Whittaker:

Primary Productivity of the Biosphere. Springer-Verlag, Berlin, Heidelberg, New York.

Nichiporovich, A.A. (1968): Evaluation of Productivity by Study of Photosynthesis as a Function of Illumunation. Functioning of Terrestrial Ecosystems at the primary Production Level. Proceddings of the Copenhagen Symposium 1965. Ed. by F.E. Eckardt. Natural Resources Research 5, UNESCO, Paris.

Patefield, W.M. and R.B. Austin (1971): A Model for the Simulation of Growth of Beta vulgaris L. Ann. of Bot. 35, p. 1227-50.

Paterson, S.S. (1956): The Forest Areas of the World and its Potential Productivity. The Royal University of Göteborg, Sweden, Department of Geography.

Penning de Vries, F.W.T. (1975): The Cost of Maintenance Processes in Plant Cells. Ann. of Bot., Vol. 39, No. 159, p. 77-92.

Ryabchikov, A.M. (1968): Hydrothermal Conditions and the Productivity of Plant Mass in the Principal Landscape Zones. Vestn. MGU, Gorgr. 5. Cit. in Bazilevich et al. (1971) op.cit.

Solar Radiation and Radiation Balance Data (The World Network) (1970): Annual Data 1964-1968. (1974): January-December 1974. USSR Chief Adminstration of the Hydrometeorological Service. A.I. Voeikov Main Geophysical Observatory. Hudrometeorological Publishing House, Leningrad.

Thomas, M.D. and G.R. Hill (1937): The Continuous Measurement of Photosynthesis, Respiration and Transpiration of Alfalfa and Wheat Growing Under Field Conditions. Plant Physiology, 12, p. 285-307.

Wit, C.T. de (1959): Potential Photosynthesis of Crop Surfaces. Neth. J. agric. Sci., Vol. 7, p. 141-149.

Wit, C.T. de (1965): Photosynthesis of Leaf Canopies. Versl. Landbouwk. Onderz. No. 663/Agric. Res. Rep. 663. Wageningen.

Wit, C.T. de, R. Brouwer and F.W.T. Penning de Vries (1970): The Simulation of Photosynthetic Systems. Prediction and Measurement of Photosynthetic Productivity. Proceedings of the IBP/PP Tecnical Meeting Trebon, 1969, Wageningen 1970.

TERRESTRISK-ØKOLOGISKE UNDERSØGELSER AF VANDINDVINDINGSEFFEKTERNE I SUSÅ-VENDEBÆK OMRÅDET

STEN FOLVING

Folving, Sten, 1978: Terrestisk-økologiske undersøgelser af vandindvindingseffekterne i Suså-Vendebæk området. Geografisk Tidsskrift 77: 12 - 24, København, Juni 1, 1978.

For some areas with humid soils in Central Zealand the development has been analyzed and on the basis hereof the consequences of a possible future exploitation of groundwater on the ecological conditions are evaluated.

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INDLEDNING

Den stærkt stigende efterspørgsel efter ferskvand til bl.a. storbyområderne har betydet, at der er anlagt mange grundvandsindvindingsanlæg. Produktionen fra disse anlæg har været igangsat, uden at man på forhånd vidste, hvilke effekter en grundvandsindvinding ville få for de landskabelige/økologiske forhold i og omkring kildeområderne. Derfor satte Miljøministeriet en række undersøgelser igang efter en ansøgning fra Københavns Vandforsyning om indvindingstilladelse i Suså-Vendebæk området. Hovedvægten blev lagt på opstilling af hydrologiske modeller; men også de overflademæssige, arealindholdsmæssige aspekter blev inddraget. Institut for Økologisk Botanik blev bedt om at foretage vegetationsanalyser i de områder, der kunne forventes berørt. Geografisk Institut fik til opgave at udføre undersøgelser omkring de arealanvendelsesmæssige konsekvenser, samt konsekvenserne for tørvedannelsen og jordbundsudviklingen i de fugtige områder i vandingsindvindingsområdet.

Forfatteren fik i efteråret 1976 overdraget en del af arbejdet. Formålet skulle være at bedømme de eventuelle konsekvenser, en grundvandsindvinding ville få for den arealanvendelsesmæssige udvikling i området, idet udgangspositionen skulle fastlægges på grundlag af en analyse af den »naturlige« udvikling, der i forvejen var foregået i området. En del af arbejdets resultater fra enkelte mindre lokaliteter vil blive præsenteret i det følgende.