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Forum

Appropriateness of instrumentation for agro-ecological research in low-income developing countries

Introduction

Recent events in certain African countries have highlighted the critical nature of their food production and the catastrophic results which can occur when adverse natural forces impinge on fragile ecosystems. The need for ecological research in such areas is self evident and represents an important facet of the total endeavour aimed at solving or at least ameliorating the problem.

The measurement of environmental parameters in the management of crop space and an understanding of the crop's response to the environment is important in assessing the potential for sustained agriculture within an ecological framework.

This paper briefly examines the problems of such instrument-based research in low-income developing countries.

The existing situation

Recent advances in electronics have led to an increased sophistication and complexity in field-instrument design. The miniaturization of circuits resulting from the advances in semi-conductor device technology is revolutionizing field instruments in the same way it revolutionized micro-computers (Page, 1985). However, the restricted demand for electronic field equipment has not always led to price reductions or 'user friendliness', as has been the case with home based consumer items using semi-conductor technology.

Lacking the specialist knowledge which has gone into the development of field equipment, the majority of users may not appreciate the limitations on accuracy. Moreover, the inclusion of internal calculation facilities is now commonplace and the fact that some commercial equipment has the facility to inter-face with a micro-computer can further separate the user from understanding the actual working processes of the equipment. It also aggravates the problems of maintenance and trouble-shooting.

However, many pieces of non-electronic equipment may also be used in ecological research and some of these may be relatively simple. Simplicity and accuracy, resulting from an easier understanding of the principles of operation, leads to more universal use and acceptance, e.g. the use of the Gunn-Bellani radiometer in East and West Africa. Also in the frequent requirement for multi-point measurements, such simple equipment may be successfully used to obtain interpolations between more sophisticated sensors, e.g. the Piche evaporimeter as a wind sensor (Stigter *et al.*, unpublished).

It would seem axiomatic that countries or global regions which have a high risk potential for food production and ecological problems are the ones least able to support the research to ameliorate them. The level of local skills and lack of money are important contributory factors that hinder the necessary research in such places.

Bilateral and multilateral donors give assistance in the form of equipment or money to buy equipment. While such donor support is of obvious benefit to the recipient country, problems can and do occur. For example: the requirement to purchase only what is available in the donor country can set limitations; mismatch between the real requirements and the specification of the donated item can result in the equipment not being used, as can the delivery of non-functional or partly functional equipment; the difficulties experienced with insurance claims and long delays between the initiation of purchase and eventual supply can create serious problems.

The rapid advances made in electronics, coupled with long order and delivery times can mean that an improved model of the equipment may have been released in the donor country prior to receipt of the older model by the developing country. This may lead to difficulties in obtaining spare parts and also problems of maintenance can lead to equipment soon becoming non-functional. The cost and complexity of some commercial equipment can discriminate against local researchers in developing countries since they may have to face unexpected expenses when spare parts are needed or, due to the absence of local maintenance skills, overseas maintenance is required. The lack of scientific journals, technical books and frequently maintenance manuals may add to these disadvantages. Very few donors provide funds or back-up for these eventualities. The old adage of biting off more than one can chew can be applied in many cases of equipment purchase. All the problems of commercial equipment to which we have referred, will naturally limit its distribution in a developing country and this, in turn, limits the amount of data acquired, possibly the location of the work and also the process of learning through 'hands-on' experience.

Appropriate instrumentation

Clearly it can be appreciated that some commercial equipment may or may not be suitable for use in developing countries. In the case where the basic functioning of the equipment is suspect, the researcher in a developing country may not have the back-up facilities to investigate the problem. Also the climate and environment may reduce the operating lifetime of an instrument: thus the radiation load on equipment and sensors, the effects of dust, storage at high humidity, rough roads, fluctuations in mains power supply, shortage of batteries etc., may render the instrument inappropriate for use in the conditions that prevail. The fact that an instrument may not perform well under such conditions may not have been apparent to the manufacturer or local researcher at the time when the equipment was ordered. Also what may be minor physical inconveniences in the use of some equipment in temperate climates can become major ones in extreme field conditions.

Lack of technical skills is one of the major problems which faces a developing country. Although there may be the opportunity for both local and overseas training, 'hands-on' experience in a local situation would seem to have many benefits. The involvement of local staff in, for example, small electronics projects or investigations into the functioning of equipment raises the level of skills in the local scientific community and forms a basis for further training. The need for many replicate measurements in ecological research coupled with technical staff having only basic skills may necessitate the use of equipment that is both cheap and easily used. Through investigations into the accuracy or functioning of commercial equipment it may be possible to bring simpler and cheaper alternatives into use and train staff simultaneously. Donor projects which provide training and technical support in co-operative projects can be invaluable in assuring that research and training efforts do not come to a premature end.

In this context, appropriate instrumentation should not just be limited to the question of which commercial equipment is suitable for use in a developing country but should also involve consideration of whether or not suitable equipment can be produced locally, such equipment being constructed with a view to its appropriateness, e.g. its simplicity, accuracy, effectiveness, ease of construction, maintenance, etc., bearing in mind the local skill levels and materials available. We should involve ourselves with innovation rather than invention: innovation meaning the use of existing technology in an appropriate way.

The early stages of developing a capability in the production of appropriate instruments or in the assessment of simpler alternative commercial ones, involving as they will some training, should initially be applied to the simplest but most useful instruments. However, eventually it may be possible to test complex commercial ones, in some cases using relatively simple techniques, when skill levels have elevated sufficiently. If the construction of an electronic instrument is being considered, two main problems should be recognized and their implications assessed.

Firstly the levels of skill available will probably dictate not only the complexity of the instrument construction to be attempted but also the probability of its successful completion. A project to make a piece of complex equipment is less likely to succeed than one which aims at a simpler, less ambitious goal. Failure does little to encourage further attempts, whereas success with a simple instrument enhances local confidence.

Secondly, because of import duty and sales tax, etc., it is possible that the components needed to construct an instrument locally may cost a lot more than initially expected. This is particularly true if the instrument is complex and uses advanced electronic technology. There is even the risk that local manufacture may cost more in parts than importing the ready-made item. The parts may not be locally available anyway and having to order them from overseas can involve long delays, leading to a loss of impetus and interest in addressing the problem.

In most developing countries, whether assessing either simple or complex commercial equipment or encouraging staff to construct equipment, the training aspect may be expected to become an important common factor, since without elevating the level of skills the problems encountered with commercial equipment or the prospects of more data being obtained via cheaper alternatives may not be solved.

Examples can be cited to illustrate the problems outlined above, their attempted solutions and their incidental gains (spin-off). Many readers could add to this list, as we ourselves could.

Alternative, simple non-electrical equipment has been assessed for its appropriateness in measuring solar radiation in Tanzania (Stigter & Waryoba, 1981; Stigter, Kainkwa & Musabilha, 1987). Here the Actinograph and Gunn-Bellani radiometers were tested against more sophisticated equipment. 'Spin-off' occurred since skill levels of local staff were increased. At the University of Nairobi simple electrical equipment has been built for solar radiation measurements in crops (Coulson & Musyoki, unpublished). This project attempted to produce a cheap appropriate instrument capable of wide distribution. The 'spin-off' in training, both locally by 'hands-on' and via an overseas-linked project, lead to printed circuit board fabrication and the change from analogue to digital output with future considerations for data storage. Relatively simple existing technology has been ingeniously used by Newman (1985) in the solution of the real problem of simultaneous multi-point solar radiation sampling.

At the Universities at Nairobi and Wageningen the attempt to understand more fully the limitations of some field solar radiation equipment for use inside crops is providing projects for graduate students in physics and micro-electronics. Such endeavours provide excellent practical interdisciplinary training and research opportunities. At the University of Nairobi, interest in flower abscission in beans (Kamweti & Coulson, 1984) led to a more complex electronic development exercise through the development of a temperature data logger (Namuye, 1986). This was another interdisciplinary problem which provided a student with the real practical problem of producing a solution locally, assisted by some technical backing through an overseas-linked project.

Simple equipment for temperature measurements in air and soil has been made when there was no equipment available locally (Coulson & Taylor, 1984). Some problems associated with commercial equipment used for the measurement of leaf temperatures have been investigated and overcome (Coulson, 1985; Coulson *et al.*, unpublished). These endeavours provided training as well as leading to the production of a prototype instrument whose simplicity and cheapness could encourage its construction by local researchers (a training situation) and, importantly, a potential for the wider spread of local data acquisition (Coulson & Musyoki, unpublished). Problems of non-contact temperature measurements using simple infra-red thermometers (IRT) have been addressed at the University of Dar-es-Salaam (Stigter, Jiwaja & Makonda, 1982a; Stigter, Makonda & Jiwaji, 1982b, 1983; and Stigter, Mwampaja & Kainkwa, 1984a). Besides cost, IRTs may suffer from other drawbacks such as calibration. Using 'commonly' available equipment and locally developed techniques it was possible to improve the performance of a non-commercial Dutch IRT. Initially, the thermocouples necessary for testing the IRT were made in Holland but as the project progressed it became possible to initiate their fabrication at Dar-es-Salaam as well as developing the appropriate methodology for the preparation of the calibration surface. The development of appropriate techniques and training were important results of this project.

The use of Piche evaporimeters as simple alternatives to expensive commercial equipment for assessing wind and air movement has been investigated by Stigter & Uiso (1981), Stigter, Uiso & Rashidi (1984b), Stigter *et al.* (unpublished) and Ibrahim *et al.* (unpublished). The use of naphtha balls for similar work in the tropics is being studied at Edinburgh (J. Grace, personal communication) and Wageningen. Such cheap methods should lead to the possibility of simultaneous multi-point sampling being possible, which is a problem at present because of the cost of commercial equipment.

Gypsum blocks for the measurement of soil water have been investigated at the Universities of Nairobi and Wageningen. The blocks were introduced when commercial soil psychrometers which had recently arrived failed to provide data. The validation (or otherwise) of these blocks, besides being necessary for postgraduate experimentation, provided training for associated technical staff as well as other postgraduates.

For the integration of solar irradiance data, problems of maintenance, repair and power supply have been addressed at the University of Dar-es-Salaam (Stigter & Mabuba, 1980; Stigter & Kainkwa, 1983) and at the University of Nairobi. Attempts to find solutions to difficulties with maintenance and repair have been made by technician training through both a Dutch University Co-operative Project and the Universities of Nairobi/York (UK) Micro-computing project.

Discussion

In situations where equipment is necessary for research, donor projects with overseas support, referred to as 'back-stopping', have an advantage because they can provide urgently needed components, advice, information or training and the format of the training can be adjusted to suit the particular problem at hand. Such 'back-stopping' can also be invaluable in assuring that research and training efforts do not come to a premature end.

In the case of large or complex overseas-linked projects the existence of a salaried project officer, earmarked as the representative in the developed country, is more likely to ensure success than the situation where the jobs are done on a part time or *ad hoc* basis by less committed personnel. Inherent flexibility in project organization would seem to be the key in many situations, though such flexibility is usually difficult to build into projects and seems unpopular in terms of donor objectives. It seems quite clear to us that by addressing the problems of appropriateness of equipment, better formats for research projects will be found in the future.

It is important that researchers and manufacturers of equipment in developed countries, who may have no first hand experience of research in developing countries, appreciate that there can be numerous, and sometimes ambiguous, constraints on such research. More importantly there is a need for researchers and higher level teachers in developing countries to identify the major constraints and to be bold enough to state them no matter how prosaic they may seem initially.

Unless we continue to find ways of dealing with the problems outlined, developing countries will be increasingly and adversely affected.

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References

Coulson, C.L. & Taylor, A.R.D. (1984) The construction of a thermistor reader to allow the continuous recording of temperature. *Kenya Journal of Science and Technology, Series B,* **5**, 67-72.

Coulson, C.L. (1985) Leaf temperatures of *Phaseolus vulgaris* — a warning. In *Phaseolus. Beans Newsletter for Eastern Africa. No. 3.* Ministry of Agriculture, National Horticultural Research Station, Thika, Kenya.

Kamweti, M.W. & Coulson, C.L. (1984) The effect of water application on flower abscission on three bean cultivars of *Phaseolus vulgaris.* Nairobi/California, Bean/Cowpea/CRSP 1984 report 62–75. Center for International Programs, Michigan State University, East Lansing, Michigan 48824-1035, USA.

Namuye, S.A. (1986) *Low cost, low power data acquisition system.* MSc thesis, Department of Physics, University of Nairobi, Nairobi.

Newman, S.M. (1985) Low cost sensor integrators for measuring the transmissivity of complex canopies to photosynthetically active radiation. *Agricultural Meteorology,* **35**, 243–254.

Page, E.W. (1985) Semiconductor device technology and digital system design. *Computers and Electronics in Agriculture,* **1**, 5–29.

Stigter, C.J. & Mabuba, K.I. (1980) Application of a cumulatively integrating recorder in solar radiometry. *Zeitschrift für Meteorologie,* **30**, 60–62.

Stigter, C.J. & Waryoba, J.M. (1981) Campbell-Stokes data for radiation calibration purposes in East Africa. *Archives of Meteorology, Geophysics and Bioclimatology, Series B,* **29**, 99–109.

Stigter, C.J. & Uiso, C.B.S. (1981) Understanding the Piche evaporimeter as a simple integrating mass transfer meter. *Applied Scientific Research,* **37**, 213–223.

Stigter, C.J., Jiwaji, N.T. & Makonda, M.M. (1982a) A calibration plate to determine the performance of infrared thermometers in field use. *Agricultural Meteorology,* **26**, 279–283.

Stigter, C.J., Makonda, M.M. & Jiwaji, N.T. (1982b) Improved field use of a simple infrared thermometer. *Acta Botanica Neerlandica,* **31**, 379–389.

Stigter, C.J. & Kainkwa, R.M.R. (1983) A method of acquiring accurate radiometer data despite frequent interruptions in mains electricity supply. *Agricultural Meterology,* **16**, 141–144.

Stigter, C.J., Makonda, M.M. & Jiwaji, N.T. (1983) Sensitivity of simple infrared thermometers. *Journal of Physics. E: Scientific Instruments,* **16**, 613–614.

Stigter, C.J., Mwampaja, A.R. & Kainkwa, R.M.R. (1984a) Infrared surface and thermistor sub-surface temperatures explaining the thermophysical character of grass mulches. Proceedings of Second Symposium on Temperature Measurement in Industry and Science, International Measurement Confederation, Suhl, 523–531.

Stigter, C.J., Uiso, C.B.S. & Rashidi, A.M.G.M. (1984b) Evaporation data from a Piche evaporimeter — a

comment using Tanzanian results. *Journal of Hydrology,* **73,** 193–198.
Stigter, C.J., Kainkwa, R.M.R. & Musabilha, V.M.M. (1987) A near-equatorial comparison of two instruments measuring diffuse solar radiation. *Zeitschrift für Meteorologie,* **37,** 161–164.

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Quo vadis?

'Numerous ecological physiologists perceive a lack of direction in the field, or perceive their work as adding minor entries to a vast encyclopaedia of adaptations whose broad outlines are already well established!' Thus writes Martin Feder in a new book, of which he is joint editor, entitled *New Directions in Ecological Physiology* (Feder *et al.*, 1988). The aim of this multi-author work is to revitalize physiological ecology by attempting to define goals and future directions for it. The volume emerged from a workshop on the subject and conveys some of the spirit of that by incorporating lively discussion sections at the end of each chapter. The final product consists of 18 chapters involving 26 contributors and discussants. As might be expected, the emphasis throughout is on adaptational aspects of physiological processes and these are addressed by considering comparative approaches successively at interspecific, intraspecific and intraorganismic levels. It should also be noted that animals are exclusively the subjects of these approaches.

Clearly this kind of approach touches intimately on the interests of *Functional Ecology* (Calow, 1987a,b) and here I draw attention to some of the general questions raised in the book that will be of particular interest to the readership of this journal.

In a central chapter (Chapter 3) Feder himself identifies a series of key questions for physiological ecology that are worth rehearsing. It is claimed, some of these have been treated very thoroughly in the past and others certainly suggest new directions for the future. What follows is a summary and paraphrase of these questions together with a short commentary on them.

Questions thought to have been answered

1 Do physiological characteristics vary among organisms or are physiological characteristics similar in different organisms?
2 Is the variation in physiological attributes random, or does it show pattern?
3 Is the pattern of physiological diversity consistent with the effects of natural selection?
4 Does variation in physiological characteristics provide useful insights into the physiological relationships of animals?
5 Does the analysis of physiological diversity describe general principles of adaptation?

There was an early view, probably based on a preoccupation with human and mammalian physiology, that 'there has been no evolution function; all living things have certain fundamental metabolic activities' (Woodger, 1929). However, thanks to the seminal contributions, from the 1940s onwards, of scientists such as George Bartholomew, Knut Schmidt-Nielsen, and Per Scholander (see Chapter 1 of Feder *et al.*, 1988) both comparative and environmental physiology have subsequently exposed a considerable amount of physiological variation that does appear to be adaptive. Yet most of this work has been concerned with *correlating* metabolic with environmental variation on both a spatial and temporal scale — and this *a posteriori* approach has a number of inherent problems (Calow, 1987a). Moreover, should physiological ecology just be concerned with documenting yet another example of adaptation to extreme environments, or geographical cline in a physiological trait, or local zonation in physiological traits relative to environmental zonation in physicochemical conditions, etc? If not, where do we go from here?

Questions that need answering

The first two of these relate to the sheer complexity of organization of physiological systems and processes within organisms.
6 How can highly complex and integrated systems evolve by selection of random variation on individual traits? Darwin himself admitted that contemplation of the evolution of the eye sent him into a cold sweat; and the same would presumably have gone for evolution of delicately-balanced and very complex metabolic pathways at the basis of all physiological processes had he known about them.
7 What constraints does this organismic complexity impose on the evolution of physiological pro-