Anticipatory Systems and Sustainable Development: Modelling the Genesis and Management of Banded Vegetation Patterns in Niger

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Abstract

Sustainable development, creating no handicap for future generations, requires an anticipatory synchronisation of its different population and economic aspects. Population responses to environmental pressures may be oriented in three main directions: work intensification, migration, and family size limitation. All three of them may be considered as anticipatory strategies. Many semiarid wooded areas present vegetation bands which have been recently modelled. This model can be used for anticipatory management allowing a sustainable production of firewood. Coherent forestry policy, like other economic policies, should induce population changes compatible with the available resources.

Keywords: Firewood, Reafforestation, Sahel, Sustainable development, Tiger bush.

Introduction

Anticipatory behaviours may be evidenced at all levels of economic or political organisations. Multinational companies try to anticipate market evolution several years in advance. Political organisations should anticipate evolution for the following generations, even if they are usually overwhelmed by urgent problems or short-term issues. At the individual or family levels, many decisions seem to be guided by traditional or spontaneous reactions. In fact, many capital decisions related to savings or family size are influenced by ideas on society evolution. In the long-term, they may be modified by changes in property or social security laws. These concepts are well documented in industrialized countries. Do similar anticipatory behaviours apply in emerging or developing countries ?

This communication will try to emphasize the important role of anticipation in all aspects of socio-economic projects compatible with sustainable development, i.e., with *development which meets the needs of the present without compromising the ability of future generations to meet their own needs* (World Commission on Environment and Development). This definition do not require a steady state in economy and population, which may grow as long as future generations are not handicapped. Zero population-growth is a difficult objective (Debesh Bhattacharya, 1993) but extreme population changes are not desirable: too large population growth impedes adapted investments in education, medical care and social security, as well as in economics, while declining populations disappear progressively in the absence of immigration. Important references on population and development (as those cited at the end of this communication) can be found in the Office of Population Research, Princeton University, U.S.A. (*http://popindex.princeton.edu*).

International Journal of Computing Anticipatory Systems, Volume 1, 1998
Ed. by D. M. Dubois, Publ. by CHAOS, Liège, Belgium. ISSN 1373-5411 ISBN 2-9600179-1-9

Development projects are characterized by large ranges of time constants. Technical improvements may require 3 to 5 years for classical agronomic projects, 5 to 20 years for firewood forestry, 15 up to 100 years for timber forestry. Socio-economic integration may be completed in few years for classical consumer products (cars, computers, electronic devices, etc.) but may require decades for cultural adaptation (e.g., for food or working habits). Health and medical time constant may range between few days for emergency assistance (food, vaccination, etc.) up to 20 years for integrated health services (hospitals and rural care posts). Population doubling time may be as low as 20 years. Social times may range between few days for mass media up to few years for most political decisions ("before the next elections") ! This large range of time constants is one of the main problem in integrated development. It may simplify the discussion of long term development (e.g., forestry and population) if we assume that short-term processes (such as firewood prices or transport) will adjust themselves.

The first part of this communication will be devoted to the analysis of recent publications in order to estimate the role of *anticipation in population evolution*. The second part will introduce a forest model which could be used for the *anticipatory management* of specific Sahelian wooded vegetation. The Conclusion will present some comments on recent forestry policies in Sahelian countries and especially in Niger.

Anticipation and Population

Population responses to socio-economic changes or to environmental pressures may be quite complex. In 1963, Davis formulated the theory of multiphasic population responses, oriented in three main directions: **work intensification**, **migration**, and **family size limitation** (Kalipeni 1996a).

Work intensification depends on local opportunities and may concern the preparation of new arable lands by slash-and-burn techniques or by terrace construction. Fertilizer are usually too expensive and population increase may have a negative impact on crop yields when fallow rotations are reduced to few years. In some places, peasants may also try to get 2 crops per year. In Sahel, where the rainy season is very short, second crops are only possible near permanent rivers and are now relatively successful. Close to towns, work intensification may concern craft industry. *Anticipation* plays the same role in rural work intensification as in other economic activities.

Migration is a classical response to economic changes in many countries, specially in Sahel countries with a long tradition of nomadism. Seasonal migration to the nearest town is quite common and is generally reversible. Long distance migration may be irreversible due to travel expenses. In all cases, migration is a major factor of cultural changes and of know-how transmission. The important role of anticipation is suggested by the following citation "Certainly there is much unemployment and underemployment in the city, but there is also the chance of a fortune, and the latter weighs heavily in the peasant's *anticipation* of the economic return to his migration" (Keyfitz, 1996).

Family size limitation due to long term effects of socio-economic conditions has been summarized by the *demographic transition model*, which describes the usual transition from a *initial population level* with high birth rates and death rates to a *final population level* with low birth rates and death rates. In most countries, the death rate decrease has preceded the birth rate decrease, leading to a large population increase. The demographic transition model is well documented for Europe (*XIX*th century) and for other Northern countries. A similar behaviour has been evidenced on all continents except Africa. Some African countries may be going through the initial stages of the fertility transition (Kalipeni 1996b). A global model of world population based on a detailed statistical analysis of these demographic data, has recently predicted that the world population will probably level off at around 11 billions inhabitants in 2100 (Lutz, 1997).

The role of *anticipation* in the two extreme population levels has been well described by Kalipeni (1996b): The first citation concerns the initial population level: "Because of comparatively high childhood mortality throughout the developing world, many families *have felt the need* to have more children to ensure that some will survive to adulthood. This pattern is further reinforced by the need for sons as social security in old age.". The second citation concerns the transition toward the final population level: "Rapid declines in infant mortality rates, improved maternal and child care, rapidly increasing attainment of formal education by females, and increased use of effective contraceptives have all contributed to the onset of a fertility transition, especially in northern and southern Africa."

In equatorial and tropical Africa, Kenya is probably one of the first country showing a significant decrease in fertility rate (4.5 children born per woman), while many tropical African countries still have a fertility rate above 6. This recent fertility decline has been analyzed by Robinson et al. (1995) with a paradigm requiring three necessary conditions for a fertility transition (Coale, 1973): (1) couples must be able to conceptualize and accept logically and emotionally their own ability to control their fertility; (2) they must perceive that it is in their own self-interest to limit births; (3) they must have reasonable access to an acceptable and reliable means of controlling fertility. The two first conditions rely on the *anticipatory behaviour of couples* while the third one requires a *social anticipation*, providing adapted family planning services, especially in rural area. This third condition is usually not satisfied in Africa, except Kenya.

Anticipation and Forestry in Sahel

Development, really sustainable for centuries, should strongly rely on *physically renewable sources of energies* (such as sun, wind and waterfalls) and on *biologically renewable energies* such as firewood (if reafforestation compensates for wood exploitation). This is not the case in industrial or emerging countries, where the energy demand is always increasing. Could it be the case in developing countries with still a low energy demand per inhabitant ?

In Sahel, hydraulic power sites are limited to some permanent rivers, e.g., the Niger, the Nile or the Senegal. Wind is very abrasive with its high sand content. Solar cells are promising but still too expensive. All these energy sources require large investments and maintenance funds.

Firewood is in fact the traditional source of energy for domestic use. Could its use be optimised in order to follow the expected population growth (more than 3 % on average and much more in towns, due to seasonal or permanent migrations) ? Cookstoves can be improved for a better energy usage (Kammen, 1995). They are not yet widely used, mainly for economic and societal reasons. Reafforestation and management projects have been carried out for decades. Their impact can now be evaluated in the light of fundamental results, as was done recently during a Workshop on *Functioning and management of Sahelian contracted forest ecosystems* (Niamey, Niger, 20-24 Nov 1995).

Statistical methods have been used for a long time for resource estimations and predictions. Suitable modelling should improve these forecasts. As an example, the landscape model simulating the genesis of banded vegetation patterns in Niger (Thiéry et al., 1995) can be used for anticipatory management.

Banded vegetation patterns (densely vegetated bands alternating regularly with bare areas) have been reported in many arid and semiarid zones (e.g., Sahelian *'brousses tigrées'*). They can occur if total rainfall is not sufficient to maintain a dense vegetation cover and if sufficient and uniform runoff can compensate, at least partly, for the lack of water. A landscape model has been developed to simulate the different observed structures (Thiéry et al., 1995). The *°TIGREE°* model, based on cellular automata, is derived from the *'game of life'* and depends only on two hypotheses reflecting *competition* and *synergy*: the establishment, growth and survival of a given plant is affected *negatively* by up-slope plants and *positively* by lateral and down-slope plants. Most of the structures observed in the field can be simulated with this simple model, by varying only the *competition coefficient*, the *synergy coefficient* and the number of iterations.

°TIGREE° can simulate various management scenarios such as *reafforestation within bare areas* or *optimised wood exploitation* (d'Herbès et al., 1995; Thiéry et al., 1997). Other scenarios can be tested: *drastic cuts* or *random cuts* with natural recovery or *improvement of the pioneer front* with simple techniques (e.g., small wood scattering to favour soil mixing by termites). Regeneration acceleration by *anticipatory actions* on the pioneer front can easily be estimated. Similar management scenarios can also be tested with *°TIGRFLUX°*, a more detailed version of *°TIGREE°* taking into account water fluxes. These landscape models can be used as frameworks for long-term calibration experiments, which are critically missing for the quantitative management of banded vegetation.

Conclusion

A complete management model should also include economic and sociological sub-models. *Anticipatory economic actions* are now included in new forest management schemes in Niger. Village taxes should encourage inhabitants to protect their new source of income. Newly defined land registers should mark limitations on available land, in Sahelian countries now close to overpopulation. This could trigger an anticipatory reaction of the inhabitants, leading to a decrease in population growth.

Acknowledgements

This study was partially supported by *CEA* and *ORSTOM*, with no official endorsement of personal opinions on sustainable development.

References

Cleaver Kevin M. and Schreiber Gotz A. (1994). Reversing the Spiral: the Population, Agriculture, and Environment Nexus in Sub-Saharan Africa. Directions in Development. ISBN 0-8213-2769-0. XV, 293 pp. World Bank: Washington, D.C.

Coale A. J. (1973). The demographic transition reconsidered. *International Population Conference*, Liège: International Union for Scientific Study of Population.

Davis K. (1963). The theory of Change and Response in Modern Demographic History. Population Index, **29**, pp. 345-366.

Debesh Bhattacharya (1993). A Critique of Zero Population Growth Theory. Indian Journal of Economics, **73**, No. 4, pp. 513-544.

Demeny Paul (1996). World Population Growth: Trends and Prospects, 1960-2020. In: *Resources and Population: Natural, Institutional, and Demographic Dimensions of Development*, edited by Colombo Bernardo, Demeny Paul, and Perutz Max F., pp. 25-47 Clarendon Press: Oxford, England.

D'Herbès Jean-Marc, Valentin Christian and Thiéry Jean M. (1995). *"La brousse tigrée"*: synthèse des connaissances acquises. Hypothèses sur la genèse et les facteurs déterminant les différentes structures contractées. Atelier International sur le *Fonctionnement et la Gestion des Ecosystèmes Forestiers Contractés Sahéliens*, Niamey (Niger), 20-24 Nov 1995.

Hossain Monowar (1994). Interrelationships between Population and Natural Resources: an Analytical Framework. In: *Expert Group Meeting on Population, Environment and Sustainable Development*. Asian Population Studies Series, **126**. pp. 1-9. Bangkok, Thailand.

Kalipeni Ezekiel (1996a). Demographic Response to Environmental Pressure in Malawi. Population and Environment, **17** (4), pp. 285-308.

Kalipeni Ezekiel (1996b). The fertility transition in Africa. Geographical Review, **85** (3), pp. 286-300.

Kammen Daniel M. (1995). Cookstoves for the Developing World. *Scientific American*, July 1995, pp. 64-67.

Keyfitz Nathan (1996). Internal Migration and Urbanization. In: *Resources and Population: Natural, Institutional, and Demographic Dimensions of Development*, edited by Colombo Bernardo, Demeny Paul, and Perutz Max F., pp. 269-285. Clarendon Press: Oxford, England.

Lutz Wolfgang, Sanderson Warren and Scherbov Sergei (1997). Doubling of World Population Unlikely. *Nature*, **387**, pp. 803-805.

Robinson Warren C. and Harbison Sarah F. (1995). The fertility decline in Kenya. J. International Development, **7** (1), pp. 81-92.

Thiéry Jean M., d'Herbès Jean-Marc and Valentin Christian (1995). A Model Simulating the Genesis of Banded Vegetation Patterns in Niger. *J. Ecology*, **83**. pp. 497-507.

Thiéry Jean M., d'Herbès Jean-Marc and Valentin Christian (1997). Modélisation de la réponse de brousses tigrées à différents modes de gestion. Accepted for publication in *Tendances nouvelles en modélisation pour l'Environnement.* Elsevier, Paris.

World Bank (Washington, D.C.) (1994). Population and Development: Implications for the World Bank. Development in Practice, ISBN 0-8213-2999-5. LC 94-31613. Aug 1994. X, 134 pp. Washington, D.C.