Evaluating nutrient balances in Sub-Saharan African Agriculture - assessment of the NUTMON approach

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Policy narratives

Nowhere is the power of policy narratives and paradigms illustrated more clearly than in environmental planning in developing countries.

The environmental policies promoted by colonial regimes and later by donors in Africa rest on historically grounded, culturally constructed paradigms that at once describe a problem and prescribe its solution.

Many of them are rooted in a narrative that tells us how things were in an earlier time when people lived in harmony with nature, how human agency has altered that harmony, and of the calamities that will plague people and nature if dramatic action is not taken soon.

It is not surprising that the narratives remind us more or less explicitly of the fall from Eden and are neo-Malthusian.

Allan Hoben (1995) World Development, 23, 1007-21

Nutrient balancing – a sustainability inventory …

Hitherto nutrient balancing has mainly dealt with rural areas at different scales (field, farm, catchments, etc).

Especially in sub-Saharan Africa (SSA) quite a lot of work, initiated by Stoorvogel and Smaling (1990), has been done to estimate balances at regional and even supra-national scale.

Stoorvogel and Smaling (1990) concluded, by means of data from 1982-84, that agriculture in most of the SSA countries is unsustainable.

A conclusion derived from highly negative nutrient balances.

The work by Stoorvogel and Smaling (1990) spawned a range of studies focusing on nutrient flows (The NUTMON school).

These studies once again work out negative nutrient balances for the SSA countries

In view of the observed nutrient imbalances Smaling and Fresco (1993) concluded that, agriculture in SSA is unsustainable and Stoorvogel et al. (1993) stated that a consequence of the soil mining would be declining crop production.

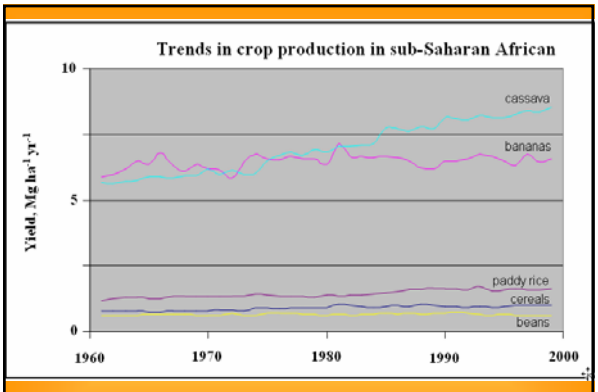


Fig. 1. Crop production in sub-Saharan Africa. Data from FAO (2000).

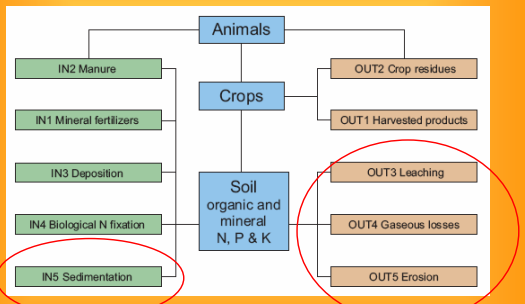
The intention of this paper is to examine the NUTMON studies in SSA.

Our focal point is whether '*the alarming annual average nutrient losses*' Stoorvogel et al. 1993: p. 227 in general reported, are credibleor merely a result of the way the nutrient losses are calculated.

The following discussion about NUTMON is not to claim or even indicate that African agriculture in general is sustainable.

Our point is simply to address whether the nutrient losses, based largely on certaintransfer functions, are reliable.

The Conceptual framework for NUTMON studies



Transfer functions

Case:

The Nitrogen Flows

With particular referece to a study in the Kisii District (Smaling et al. 1993)

The Kisii District is located near Lake Victoria in Kenya, at altitudes between 1500 and 2200 m. The district has a total land area of 220 000 ha, precipitation from 1350 to 2050 mm yr^{-1}, mean temperatures from 16.2 to 20.5 °C and about 1.5 million inhabitants.

The district is utilized for grazing, tea, pyrethrum, coffee, banana, sugarcane, maize and beans.

The clay contents in the soils are high (varies between 31 and 66%)

In 1990, in units of N, P and K, the average inputs by mineral fertilizer were 18, 13 and 3 kg and by manure 23, 5 and 25 kg ha^{-1} yr^{-1}, respectively.

An aggregated balance, calculated for 1990, revealed a deficit of 112, 3 and 70 kg ha^{-1} yr^{-1} of N, P and K, respectively (Smaling et al. 1993)

Nitrogen flows ….

Generally for the NUTMON studies, average denitrification and N leaching rates, worked out by means of transfer functions, seem rather high in comparison to ditto rates in high input agriculture in temperate regions.

In dry land low input agriculture, Baijukya & Steenhuijsen (1998), for example, estimated denitrification rates between 20 and 24 kg N ha-1 yr-1, whereas van den Bosch et al. (1998a) estimated leaching of 53 kg N ha-1 yr-1.

In their balance, van den Bosch et al. (1998a) stated that "*If no losses had occurred, the farms would qualify as sustainable with respect to soil fertility, but emission turn the full balance negative*" (ibid, 76).

Smaling et al. (1993) estimate leaching of N on the basis of studies from coarse textured soils under high precipitation regimes and high fertilizer input rates, compared to average application rates in the Kisii District.

None of the studies considers leaching of native N.

In general, the relative leaching, as also found by Walters & Malzer (1990), increases with higher fertilizer input.

In addition, usually, leaching is higher on coarse textured soils compared to more fine textured soils.

Therefore, to extend results from these studies to areas receiving limited amounts of fertilizer, *is an extrapolation from abundance to scarcity, from sand to clay, and from fertilizer N to native N.*

Leaching of N from the soils in the Kisii District, which on average were applied 41 kg N ha-1 yr-1 in manure and mineral fertilizer, was modelled to be 40 kg N ha-1 yr-1 on average.

This is an unusually high leaching relative to the N input

Smaling et al. 1993 do not show any calculation of the *total mineral soil N*. However, it is mentioned that there is between 1.6 and 4 g $N_{(total)}$ kg^{-1}soil.

The mineralization was assumed - without references – to be either 2.5 or 3% yr^{-1} of soil organic N depending on temperature zone.

That is, if the soil density is 1300 kg m^{-3}, the *total mineral soil N* i.e., net mineralization was calculated to be between 104 and 312 kg N ha^{-1} yr^{-1}.

harvest of 10 t wheat grain removes 180 kg N

Mineralization (our estimate after an exhaustive review of local and global data)

For the Kisii soils, the net mineralization loss of soil organic N is estimated to be approximately 16 kg ha^{-1} yr^{-1}

– (an order of magnitude lower that the estimates that informed the original NUTMON studies)

N leaching

Smaling et al. (1993) modeled leaching of available N as a function of average annual rainfall and clay content.

There is no feedback for e.g., plant uptake of N or evapotranspiration.

Denitrification

Based on our review of the literature we have to state that - all things considered *'denitrification may not be a significant route of N loss'* in Kisii district.

The soils included in the Kisii District balance received 41 kg N ha^{-1} yr^{-1} from manure and mineral fertilizer. From the above it is difficult to see how these soils should denitrify 27 kg N ha^{-1} yr^{-1}.

According to the few sources available a value of about 1 or 2 kg N ha^{-1} yr^{-1}, may be more reasonable.

After critically reviewing all the available information on the transfer functions – we were left with the feeling that

the quality of the science behind might perhaps be sufficient for a first and rough approximation of the rates and processes….

…but we wondered why they had not been validated and improved at all in the subsequent research (a virtual NUTMON research industry was generated during 1994 and onwards)

It is our impression that the initial NUTMON studies by Stoorvogel and Smaling 1990 and Smaling et al. 1993 have been given such a scientific status, that the single elements in the model are almost no longer questioned. Their results are turned into basic assumptions on top of which new studies are done without questioning the underlying assumptions. In that sense the initial NUTMON approach has become a 'fact'.

As of October 2005 Smaling has been cited 333 times (ISI Science Citation Index) based on 15 refereed papers and a number of reports

Undoubtedly the NUTMON school has had considerable support from (and some influence on) donors

A consequence of NUTMON can be seen in a recent report from the Intergovernmental Panel on Climate Change (IPCC, Watson et al. 200), stating that '*Soil carbon stocks have dramatically decreased in smallholder farms of sub-Saharan Africa* ... and further... *The loss of topsoil organic carbon ... has been estimated at an average rate of 0.22 t C ha–1 yr–1'*

However, the annual loss of 0.22 Mg C ha–1 yr–1, is cited from Sanchez et al. (1997) who worked out their estimate, assuming a C:N ratio of 10 in SOM and a loss of 22 kg N ha–1 yr–1. The N loss is quoted from, none but, Stoorvogel and Smaling (1990).

Basically therefore, the IPCC estimate of C loss in SSA is derived from the transfer functions elaborated by Stoorvogel and Smaling (1990).

Thus, a fair part of the *'dramatically decreased ... carbon stocks'*, reported by the IPCC, can be traced back to be a function of simple transfer functions for denitrification and leaching and another fair part is due to the assumption that eroded soil sediments are lost for agriculture.

An highly unwelcome contribution …

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Evaluating NUTMON nutrient balancing in Sub-Saharan Africa

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This paper was difficult to publish, and only received because of Intervention from 'higher powers' and because it could not be refuted by substantiated arguments

According to the present review nutrient balances elaborated by means of the NUTMON approach almost inevitably will result in substantially exaggerated nutrient losses.

Why did the NUTMON approach gain such momentum?

Is there a need for specific scientific results?

Or, are some kinds of scientific results or findings more appealing to funding agencies than others?

Or, is the process described above only the normal way to conduct science?

A final question

Land Systems Management is bound to be highly politicized…

To which an extent and how does that influence us as scientists and the validity of our work ….?