Economic Commission for Africa

Booklet on Population, Environment, Development and Agriculture (PEDA) Model

PEDA ADVOCACY BOOKLET:
The Nexus

ECA/FSSDD/01/12
November 2001

Economic Commission for Africa

BOOKLET ON POPULATION, ENVIRONMENT, DEVELOPMENT AND AGRICULTURE (PEDA) MODEL

PEDA ADVOCACY BOOKLET: The Nexus

Contents

INTRODUCTION 1

I. PEDA MODEL 2

A. What is PEDA? 2

B. The vicious circle: Theoretical foundations of PEDA 2

C. The structure of the PEDA model 4

D. Breaking the vicious circle 5

II. SOME EXAMPLES OF POLICY QUESTIONS THAT CAN BE ANSWERED USING PEDA 6

A. Policy question: Fertility reduction on food production and food security 8

B. Policy question: Education enrolment on environment, land degradation and food production 10

C. Policy question: Fertility reduction and educational enrolment on food production and food security 12

III. CONCLUSION 16

INTRODUCTION

During the past three decades, there has been a discerned shift in focus from dealing with sectoral issues to considerations of linkages. This paradigm shift is best exemplified by the discussions that have dominated major United Nations Conferences since the 1970s on Population, Environment and Food Security.

At the United Nations Conference on Human Environment held in Stockholm in 1972, discussions were mainly on the environment. By the time of the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil in 1992, the links between rapid population growth, environmental degradation and poverty were generally acknowledged. The conference, dubbed the Earth Summit, also popularized the concept of sustainable development, which raised the issue of intergenerational equity with respect to the use of natural resources. The issue of sustainability and the need to adopt a holistic approach to development problems were also underlined in the UN global conferences in Copenhagen, Cairo, Beijing and Rome where social, population, gender and food issues were discussed respectively.

It is within this general context of the new global development paradigm that management of the nexus between population, environment and agriculture has been advocated by the Economic Commission for Africa (ECA) over the last five years. The World Bank first promoted the concept in a publication[1] where the authors asserted that “their findings confirm the hypothesis of strong synergies and causality chains linking rapid population growth, degradation of the environment resource base and poor agricultural production”.

Although this synergistic relationship can be established at the grassroots level, operationalizing the concept in modern sectorally managed economies is a daunting challenge. But there are advantages to be derived from operationalizing the concept. The adoption of a holistic approach to addressing problems in the different sectors will result in better co-ordination of efforts and ensure cost-effective programmes. It has increasingly been demonstrated in the field that applying single solutions to multifaceted problems cannot achieve the desired results.

In order to understand the complex interrelationships that exist among the nexus issues – rapid population growth, environmental degradation and food security -and how changes in one nexus component affect the others, a computer simulation model known as PEDA (Population, Environment, Development and Agriculture) has been developed by ECA.

This advocacy booklet is intended to give short descriptions of PEDA and to advocate for the use of the model in adopting a holistic approach to national development and food security by policy-makers and development planners at different levels on the African continent. This idea is also supported by providing some examples of policy questions that can be answered using the model.

---

[1] K. Cleaver and G. Schriber , “Reversing the Spiral: The Population, Agriculture and Environment Nexus in Sub-Saharan Africa", World Bank, January 1998.

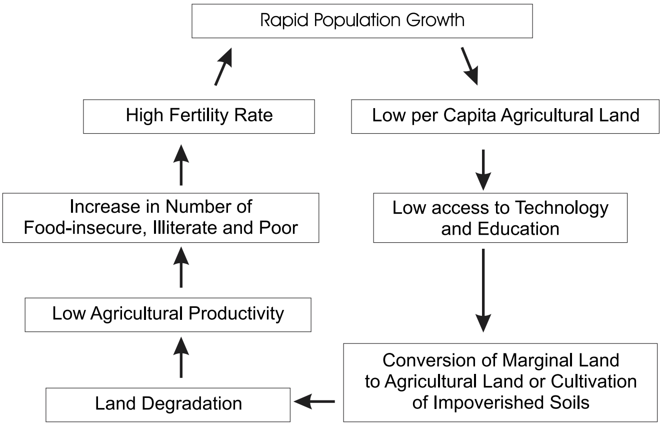
I. PEDA MODEL

A. What is PEDA?

PEDA is an interactive computer simulation model demonstrating the medium-to long-term impacts of alternative national policies on food security. The model is intended to be used in understanding within a holistic framework, the interrelationships between population change (P), some aspects of environmental change (E), socio-economic development (D) and agriculture (A). It is an advocacy tool giving answers to a wide range of policy questions regarding the nexus interactions and demonstrating the impact of different policy options in relation to the goal of ensuring food security and by implication poverty alleviation and sustainable development. Through the manipulation of scenario variables, the model enables the user to project the proportion of the population that will be food secure and food insecure at a chosen point in time.

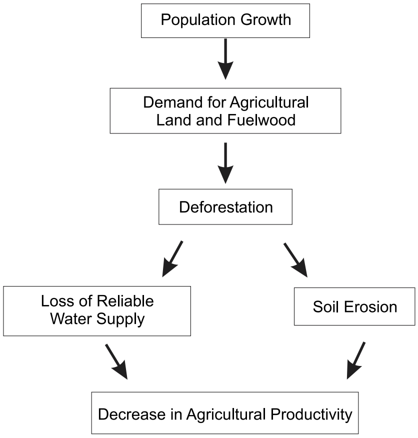
B. The vicious circle: Theoretical foundations of PEDA

Fig. 1: The vicious circle in SSA



In most of sub-Saharan Africa, population growth has been higher in the rural areas compared to the urban. As a result of lack of access to high technology and education, the food-insecure and illiterate population needs to utilize more and more land in order to continue to produce enough for their sustenance. Alternatively, they may need to continue to cultivate impoverished soils, the end result of which is a degraded landscape and lowering agricultural productivity. Correspondingly, low agricultural productivity produces a large army of economically poor and food- insecure persons who tend to increase their family sizes through high fertility parity as the only viable option for them to increase labour and also to provide security for themselves during old age. In the process, the number of food insecure or the poor in the population further increases in this cycle (Fig. 1).

Fig. 2: Interrelationships between population, agriculture and environment



In order to understand the vicious circle, it is better to illustrate how each module interrelates with each other, for example, the interrelationships between population (P), environment (E) and agriculture (A). In its simple form (Fig. 2), increasing population would lead to a corresponding demand for agricultural land and for fuelwood, the main source of energy for rural people. This process puts an intensified pressure on land and forest resources which, in turn, sets in motion rapid soil erosion and deforestation. This contributes to a loss of reliable water supply for agricultural activities. The end result is decreasing agricultural productivity and increasing numbers of food-insecure persons in the total population.

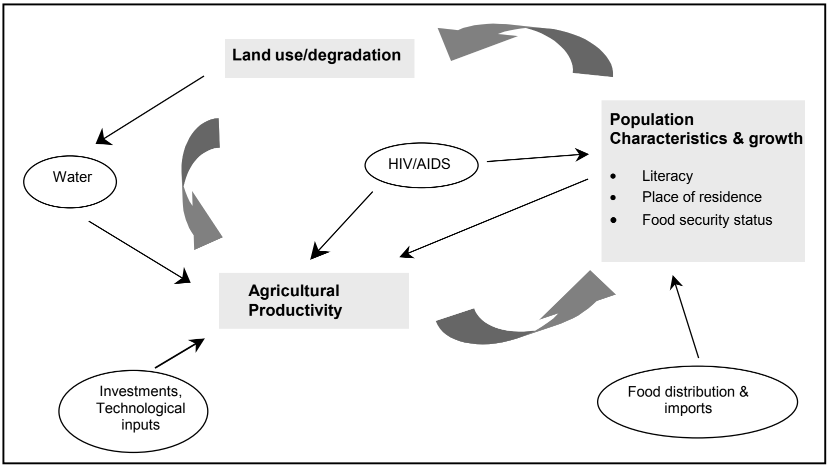
The 'vicious circle model' has recently become a very influential paradigm in the discussion around population, poverty, food security and sustainable development. It essentially assumes that high fertility, poverty, low education and the low socio-economic status of women are bound up in a web of interactions with environmental degradation and declining food production. This happens in such a way that stress from one of the sources can trap certain rural societies, especially those living in marginal areas, into a vicious circle of increasingly destructive responses. The developers of PEDA opted for this vicious circle as the underlying theoretical assumption of the model.

The vicious circle in PEDA operates through the negative impact of a fast-growing (illiterate and food-insecure) population on the natural resource base, which in turn decreases agricultural production and induces more food insecurity. If not broken, this vicious circle would lead to ever increasing land degradation and increases in the food-insecure population.

C. The structure of the PEDA model

PEDA consists of three sub-modules or segments: a population module, a natural resource module (land and water) and an agricultural production module (Fig.3). Although not immediately visible to the user, the model contains an additional food distribution segment that accounts for the inequality in access to food among different groups.

Fig. 3: The structure of the PEDA model



The population module is central to the model. It allows for multi-state population projections to determine the size of the population by three dichotomous characteristics, i.e. food security status, place of residence (urban/rural) and literacy status. In PEDA, the population of a country under consideration is broken down into eight sub-groups according to above-mentioned characteristics.

Eight sub-groups of the population are:

1. Urban / Literate / Food Secure
2. Urban / Literate / Food Insecure
3. Urban / Illiterate / Food Secure
4. Urban / Illiterate / Food Insecure
5. Rural / Literate / Food Secure
6. Rural / Literate / Food Insecure
7. Rural / Illiterate / Food Secure
8. Rural / Illiterate / Food Insecure

Each of these sub-groups is further subdivided by age (in single-year age groups) and sex, i.e., each sub-group has its own age pyramid. As part of the initialization process, the user can set age- and sex-specific mortality, fertility and educational transition rates for each population group. Dynamic future paths can be defined for fertility and mortality as scenario variables. During one-year simulation steps, a person will move up in the age pyramid by one year within the same sub-group or move to another sub-group while ageing by one year (or die). Movements between food security levels can happen in both directions, depending on food conditions in the relevant year and the food distribution function, while people can move only in one direction for education, i.e., from no (or lower) education to literacy (or higher education). Multi-state demographic projection techniques enable the simultaneous projection of these sub-groups into the future.

In the natural resource module, land and water are key elements for agricultural production. Set to 1 in the starting year, land describes both the quantity and quality of land. It considers changes over time in potential soil fertility, actual land use and land degradation. The change in the stock of land is the result of a combination of indigenous growth or regeneration and a reduction through population-induced environmental degradation. The water component, on the other hand, considers rainfall, man-made water systems (reservoirs and irrigation) and the availability of water for agricultural use.

A combination of land, water and agricultural labour force with capital investments in agriculture and technological innovation is expected to indicate the total amount of food produced in the agricultural production segment. As it is likely that all food produced in a country will be consumed by its citizens, PEDA accounts for food ready for human consumption after deductions of quantities used as seed and animal feed, quantities lost during the harvest, transportation, storage and processing. The food distribution function, available in PEDA separately for urban and rural areas of a specific country, gives estimates of the proportion of the population that is food-secure and food-insecure.

Although PEDA is by default set to be compliant with the main principles of the vicious circle at the macro-level, the negative chain of interactions is, however, not part of the model structure itself. The user can easily change the assumptions of the relationships between population growth, the natural resources and agricultural production and opt for the virtuous circle dynamics. The model does not assume increasing fertility as an automatic response to food insecurity. Rather, the food-secure and food-insecure fractions of the population are assumed to have different fertility levels, where the user can intervene by manipulating scenario variables. The virtuous chain of interactions can be assumed in several ways, e.g., no negative effect of increasing population densities on natural resources, increasing technological inputs in agriculture, a lower level of fertility in food-insecure segments of population etc.

D. Breaking the vicious circle

The vicious circle can be broken through several possible interventions in the field of food production, food distribution, education, environmental protection and population dynamics, allowing for more Boserupian visions[2] on the nexus of population, the environment and agricultural production. The power of the PEDA model is that these assumed positive or negative interactions are all part of the scenarios that can be set by the user and not hard-wired into the model.

As an advocacy tool, PEDA does not provide a single and concise answer about how to break the vicious circle in a specific country. Rather, simulation exercises are designed to be used to sensitize policy-makers, development planners and researchers on the need to adopt a holistic approach to national development, especially in the field of food security and sustainable development.

Here are some examples of the options that may be adopted to break up the vicious circles. PEDA emphasizes in one way or another the need to adopt simultaneously the whole range of options instead of focusing on one area:

---

[2] Boserup suggested that population growth and resulting increases in population density, might induce technological changes that allow food production to keep pace with population growth (Boserup, E., 1981, Population and Technological Change, Chicago: University of Chicago Press).

- Building the needed infrastructure;
- Intensification of agriculture;
- Marketing and pricing;
- Enhancing human capacity;
- Reducing rate of population growth;

Building the needed infrastructure: Poor storage and communication networks such as roads, railways and waterways have led to much post-harvest losses. Thus, the construction of efficient communication lines linking the main agricultural production centres with the rest of the country, would improve distribution and reduce losses. In addition, introduction of appropriate storage facilities and rural electrification would also reduce losses and promote food processing. This would improve food security and reduce poverty in rural areas.

Intensification of agriculture would prevent further expansion of farmlands into marginal areas, which leads to land degradation. It is possible to use the same piece of land and produce higher yields through intensification i.e., use of manure, chemical fertilizers, faster yielding plant varieties and irrigation.

Marketing and pricing: The food market has been separated from other commodity markets during the era of structural adjustment programmes (SAPs) in Africa. Thus, as food prices get depressed during bumper harvests, the prices of other commodities keep increasing. This renders farmers incapable of competing in the other markets and unable to adopt best practices. This is a major channel through which the vicious circle is perpetuated.

Enhancing human capacity: This involves strengthening the educational sector and providing requisite skills for the labour market. In this respect, efforts should be intensified not only to attain universal education for the entire population but, most importantly, to bridge the yawning gap that often exists between males and females in education. This has the added incentive of reducing people's preference for larger family sizes, which reduces population growth.

Reducing rate of population growth: Educational campaigns that are aimed at increasing the use of family planning methods among the population should be intensified. This should be done alongside improvements in education, especially female education, as a way of reducing fertility and rapid population growth.

II. SOME EXAMPLES OF POLICY QUESTIONS THAT CAN BE ANSWERED USING PEDA[3]

PEDA carries great potential as an advocacy tool through its ability to illustrate how evolutions in different sectors such as population, agriculture and the environment influence and reinforce each other. Hereunder, a number of interesting policy questions are summarized as well as the kind of answers[4] PEDA is able to give to such policy questions.

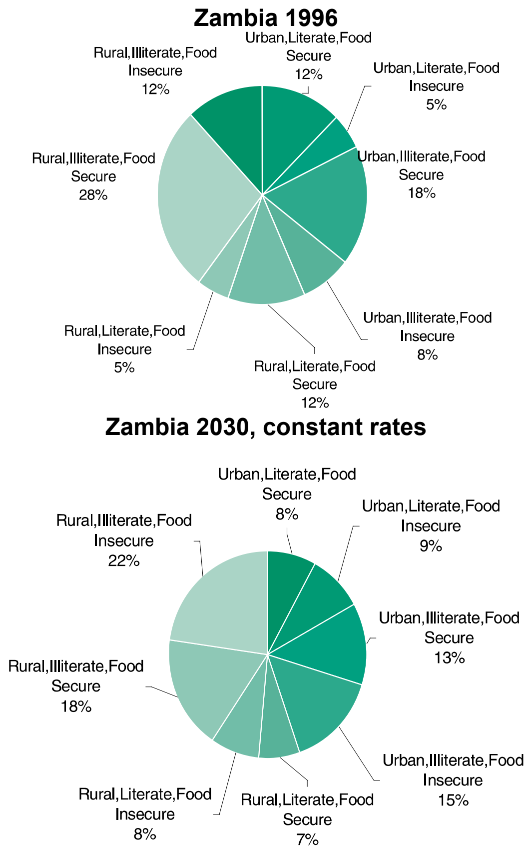
---

3 The answers given were obtained from simulation exercises undertaken with the Zambia prototype of PEDA.

4 The answers as they are given here do not give full justice to the flexibility of the model in terms of its presentation potential and output possibilities. If we, for example, talk about the food security situation in a country, we cannot only consider the aggregated food security situation on

The outputs presented are relevant for Zambia only. Although the data apply to a specific country, there is no pretence that they are accurate in any way. In most cases, the results of the projections are compared to a constant rates scenario where it is assumed that all variables remain constant throughout the projection period. An account of the initial values for population parameters in the PEDA prototype for Zambia is given in the annex. The two pie charts below (Fig. 4) illustrate the evolution of the total population by residential, literacy and food security status under the constant rates scenario.

Fig. 4: Evolution of the total population by residential, literacy and food security status under the constant rates scenarios



When the proportion of food-insecure people in Zambia was assumed to be around 30 per cent in 1996, this percentage dramatically increases under the constant rates scenario. It is expected that the proportion of food insecure will reach 55 per cent by 2030 if fertility and mortality rates, educational enrolment rates and all other factors influencing the availability of food remain at their 1996 levels.

---

a national level (as is done in most of the answers stated below) but we can further break down food security in the country by sex, urban/rural place of residence, literacy status and age group.

A. Policy question: Fertility reduction on food production and food security

Policy question:

How does a reduction in fertility rates to half their present levels by 2030 influence the food production and food security situation in a country?

Contrary to what one would expect, a reduction in fertility rates does not negatively affect the food production in a country. Under this scenario, the total amount of food produced will remain stable over the whole projection period. This is because fertility decline would have two opposing effects on agricultural production. *First*, it reduces the size of the rural labour force which is one of the major contributors to agricultural production. Given the same level of technical input, in particular of machinery use, a shrink in the labour force will definitely lead to a reduction of food production. *Second*, it limits the negative effects on the environment of high population densities in rural areas. As a result, the negative impact of fertility decline on food production through reduction of the rural labour force will be offset by the positive impact through relatively lower population densities. Hence, a reduction of fertility rates does not significantly affect agricultural production in a country. Rather, it contributes significantly to reducing food insecurity as it reduces the number of mouths to feed. In other words, a decrease in the TFR of women will result in an increase in per capita food production. Nevertheless, a reduction in fertility rates to half their present levels by 2030 alone will not eliminate the food security problem in Zambia. If no other initiatives are taken in other sectors, the total number of food-insecure people will still more than double by the end of the projection period.

Details on the projections

This question can be answered through manipulation of fertility rates as a scenario variable and projection of the total population by food security status.

As a decrease in fertility rates affects population growth and thus the population density in rural areas, it will also have a positive effect on the environment. Compared to the constant rates scenario, the total amount of land available for agricultural production will be higher (Fig. 5). This will positively affect agricultural production. However, a reduction in fertility rates also means a reduction in the rural labour force and a reduction of the total amount of food that is produced in a country. Both effects work in a different direction and tend to neutralize each other as is shown in Fig. 6. A decrease in fertility rates to half their current levels by 2030 does not automatically lead to a decrease in the agricultural output of a country in the long term.

On the other hand, a gradual reduction of fertility levels will result in a lower number of total population by 2030. This will increase the average amount of food available per capita. As such, a reduction in fertility rates has a positive impact on the food security status of the population.

In the concrete example of Zambia, a reduction of the TFR to half the level of 1996 by 2030 will result in a more than doubled total amount of food-insecure people. This figure needs to be compared to the constant rates scenario for which it is estimated that the total amount of food-insecure people will be four times higher in 2030 than in 1996 (Fig. 7).

As seen above, efforts towards lowering fertility levels alone may contribute to some extent to improving food security situation in Zambia. The expected number of food-insecure persons in 2030 will be reduced from 12.7 million under the constant rates scenario to 7.7 million under the TFR1/2 scenario. However, these efforts alone will not eliminate the food security problem in Zambia.

Fig. 5: Trends in land use in Zambia under the constant and TFR scenarios (1996-2030)

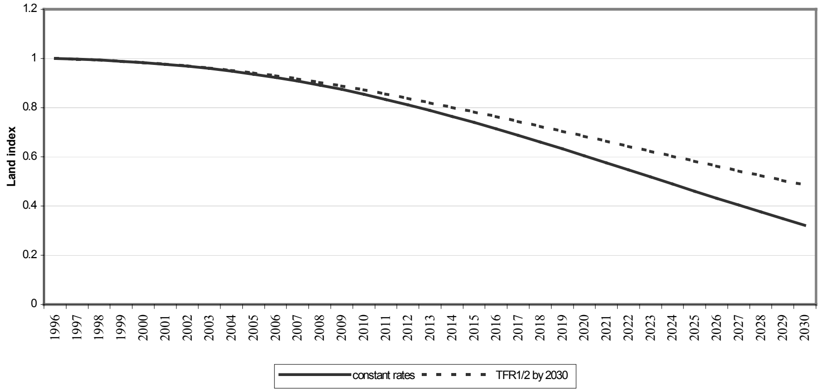


Fig. 6: Trends in food production in Zambia under the constant and TFR scenarios (1996-2030)

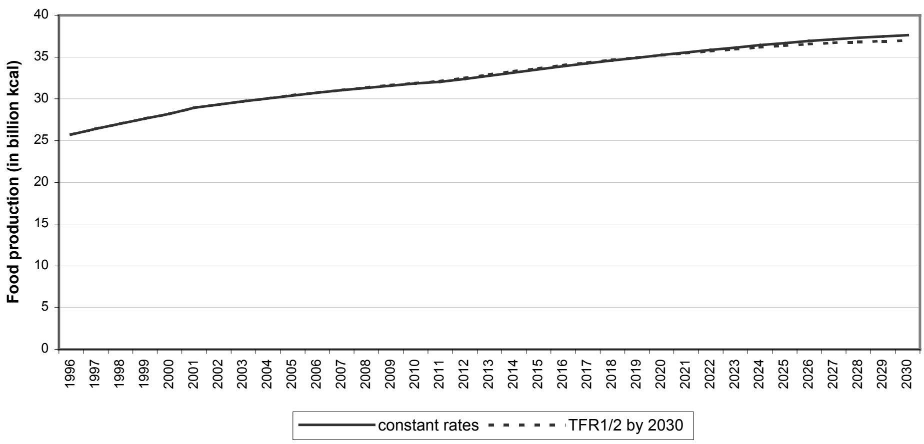
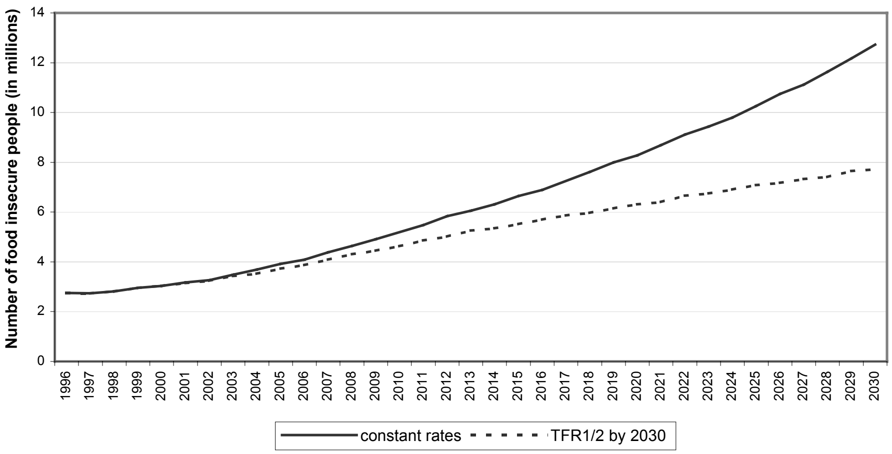


Fig. 7: Evolution of the total food-insecure population in Zambia under the constant and TFR scenarios (1996-2030)



B. Policy question: Education enrolment on environment, land degradation and food production

Policy question:
What is the impact of increased education on the environment and land degradation and food production?

An increase in educational enrolment rates has several reinforcing positive impacts on land use, agricultural production and food security. First of all, an increase in the literacy rates in a country will slow down population growth because fertility rates of literate women are generally lower than that of illiterate women. This has a positive impact on land degradation through decreased population densities in rural areas. Further, higher literacy rates also have a direct and more important impact on land use because it is especially the rural illiterate and food-insecure people that tend to deplete natural resources in their quest for survival. As such, it can be estimated with PEDA that an increase of educational enrolment rates by an additional 30 per cent will reduce the land degradation by almost half by the end of the projection period (2030). As a consequence, and also because of increase in the literacy of the rural labour force, the total amount of food produced will be almost doubled by 2030 as compared to a 45 per cent increase under the constant rates scenario. The proportion of food-insecure people will also be restricted considerably.

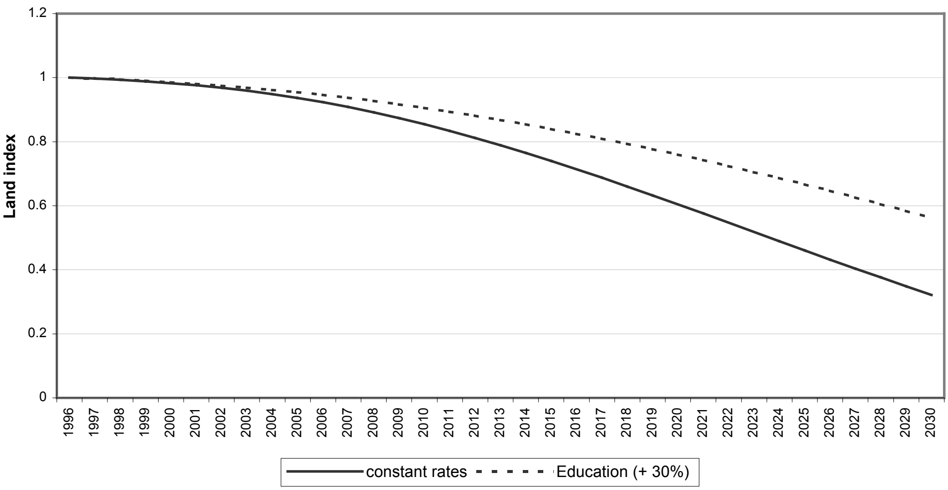
Details on the projections

To answer this question, we need to adjust the educational transition rates, treated as a scenario variable, and project the land index variable and total amount of food produced which are the two output variables in the exercise. This exercise singles out the direct and indirect effects of higher literacy on land use and agricultural production.

In PEDA, the education transitional rates are set for men and women separately for each of illiterate segments of population. They show the proportion of girls and boys in each birth cohort that will move from the illiterate to the literate status over their lifetime. We have assumed in this specific exercise that efforts to increase education in Zambia will be strengthened and as a result of these efforts, the likelihood for Zambian adolescents to be formally educated will progress by an additional 30 per cent from the level of 1996.

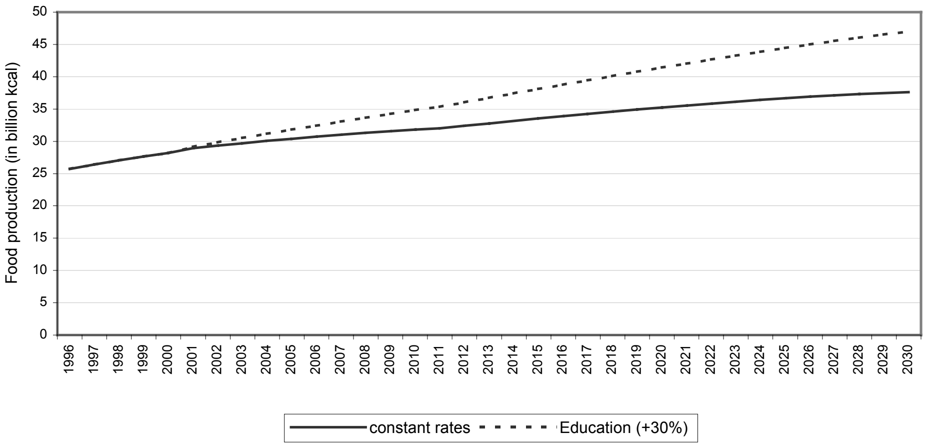
Land is treated in the model as an index. It expresses the combined result of both quantity and quality status of land (arable land and pasture). With a value of 1 for the starting year, changes in index values over time show the extent to which land will be degraded (when the index is less than 1) or improved (when the index is higher than 1) as compared to the initial year. Under the constant rates scenario, it is assumed that this value will drastically decrease to 0.3 by 2030. An increase in the literacy rate of the population, however, has a significant positive impact on preventing land degradation, as evidenced by the result of simulation exercises under the current scenario. Here, we obtained that the only efforts to increase education, other things being equal, would also lead to a deterioration of the agricultural land, but at a slower pace to reach only the level of 0.56 by 2030 (Fig. 8). This is due to the fact that literate women and men in rural areas tend to have fewer children than illiterate families. Fewer people and smaller family sizes generally put reduced pressure on land. Moreover, literate persons are more engaged in economic and social life and have knowledge on how best they can protect their living environment with available resources.

Fig. 8: Trends in land use in Zambia under the constant and education scenarios (1996-2030)



As is shown in Fig. 9, increased education also has a positive impact on food production. This is not only due to the positive impact of increased literacy on the depletion of natural resources, but also because a literate labour force tends to be more productive than an illiterate labour force. It is estimated that food production in Zambia will almost double under the educational scenario whereas it would only increase by 45 per cent under the constant rates scenario.

Fig. 9: Trends in food production in Zambia under the constant and education scenarios (1996-2030)



This example clearly illustrates intersectoral relationships; i.e. the effect of an improvement in the educational level of the population on environment and agricultural production. The effects of improved education are truly multi-dimensional. Here, we have seen only how important education is for better land management and increased food production. The socio-economic and cultural aspects of the positive effects of education can also be discussed. Another lesson that can be drawn from this example is that education makes contribution in both preserving the natural resources and increasing food production while the common sense predicates that increase in food production necessarily leads to land degradation in the medium- to the long-term.

C. Policy question: Fertility reduction and educational enrolment on food production and food security

Policy question:

What will be the impact on the environment, food production and the food security situation in the country by 2030 if the government takes combined measures to reduce fertility rates by half their present levels and increase the educational enrolment rates by an additional 30%?

We have seen, by answering two sample policy questions, that taking measures in other areas, i.e., reducing TFR by half the level of 1996 or increasing the educational enrollment rates by an additional 30 per cent, may ultimately contribute to environmental protection and increased agricultural production. Although this may give us some optimistic indications of the future, we are not yet satisfied with the results, as we expect that there will still be an increase in the size of the food-insecure population in Zambia. This question combines the two hypotheses of the previous questions. It demonstrates that by taking actions simultaneously in the interlinked areas, the goal of reducing and eliminating hunger in Zambia will be further promoted.

Details on the projections

Literate farmers tend to be more productive than illiterate farmers, literate women usually have fewer children, and literate people do not deplete natural resources to the same extent as illiterate people. In the long run, increased efforts in education have positive impacts on the protection of natural resource base, agricultural production and food security. However, the efforts in raising the literacy rate of the country alone will not be enough to combat food insecurity. If these efforts are combined with efforts to reduce fertility levels by half, we may expect to have more optimistic results in land management, food production and ultimately, the food security of the country. As shown in Fig. 10, land will be preserved to such an extent that it will be reduced to only 0.8 by 2030, compared to 0.3, 0.5 and 0.6 respectively for the constant, TFR and education scenarios. Food production (Fig. 11) will increase almost to the same level as in the education scenario, but still far above the levels of the constant and TFR scenarios. This means that investments are required in both the human development and agriculture sectors. The food security situation in Zambia would further improve in 2030 to such an extent that the number of food-secure people will reach 33 per cent of total population (Fig. 12), compared to 55, 44 and 45 respectively for the constant, TFR and education scenarios.

Fig. 10: Trends in land use in Zambia under the constant and TFR&education combined scenarios 1996-2030

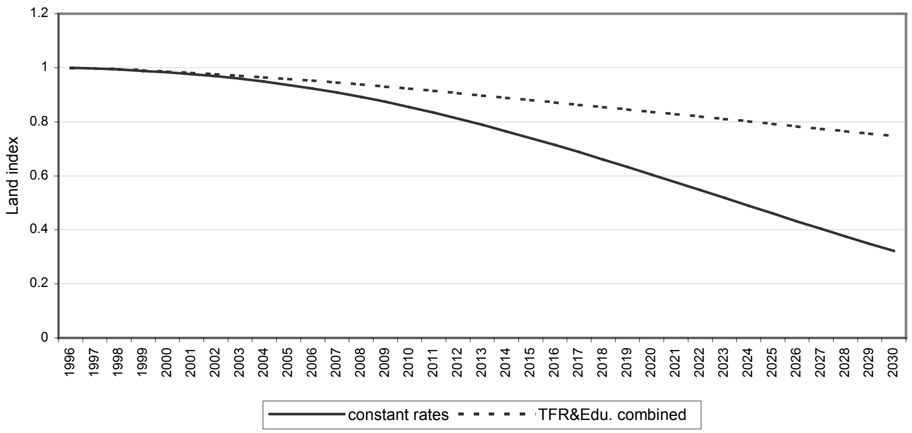


Fig. 11: Trends in food production in Zambia under the constant and TFR&education combined scenarios, 1996-2030

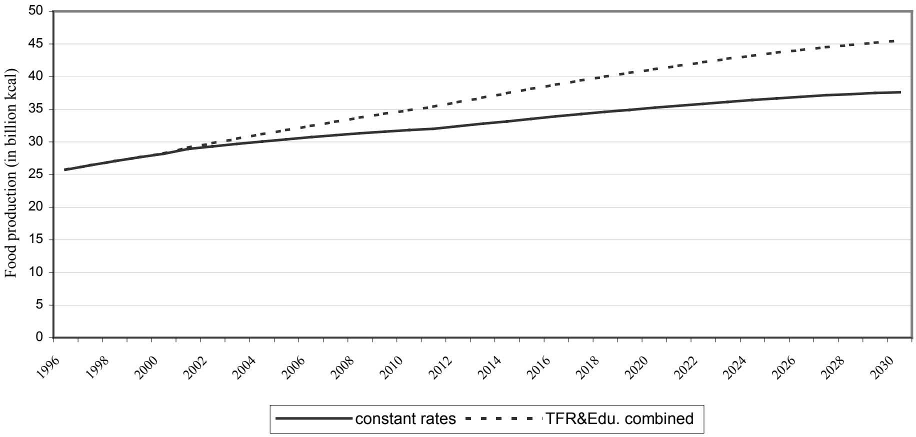
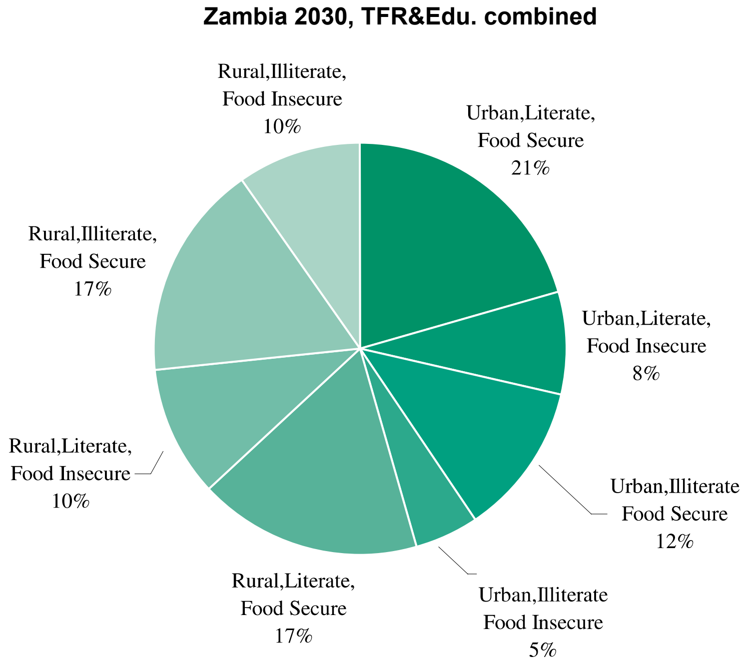
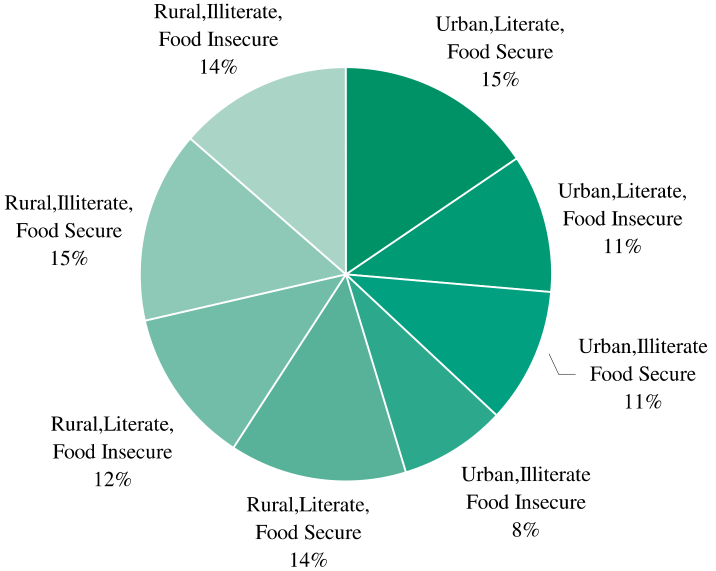


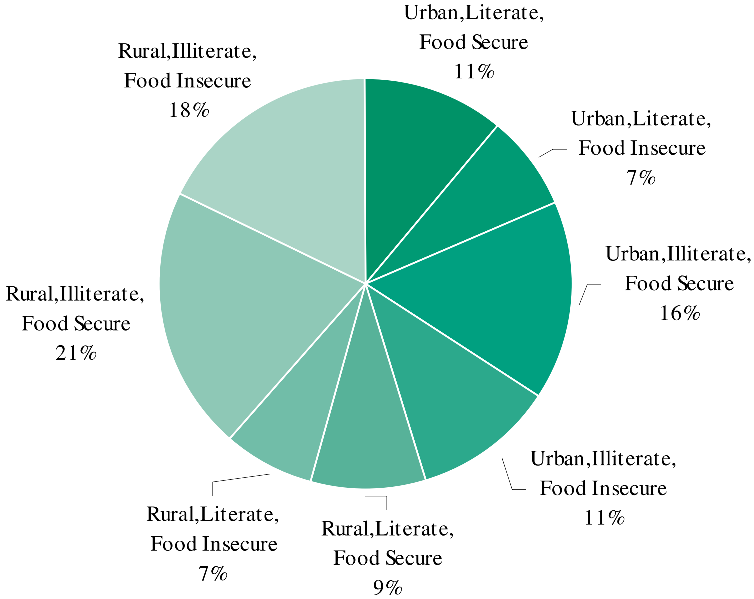
Fig 12: Total population by residential, literacy and food security status in 2030 under the TFR, education and combined scenarios



Zambia 2030, Education (+30%)



Zambia 2030, TFR1/2 by 2030



III. CONCLUSION

After pursuing sectoral development over the past several decades, there is now a growing consensus on the need to adopt a holistic approach to development. As has been demonstrated in this publication, issues of population, environment and food security are interrelated. They cannot therefore be addressed fully by only one sector Ministry. While the new development paradigm makes sense, operationalizing the nexus concept poses difficulties.

In an attempt to address these issues, UNECA has developed the PEDA (Population, Environment, Development and Agriculture) model. PEDA makes it possible to deal with cross-cutting issues and to determine possible outcomes of policy options. Policy questions can be answered with the PEDA model in a fairly straightforward manner through the manipulation of one or more scenario variables. By manipulating scenario variables, one can estimate and illustrate the effect of population dynamics on environmental degradation, agricultural production and the food security situation of the population as well as the effect of agricultural intensification and the distribution of food on the food security status of the population, and so on. Further, the model can illustrate the impact of education on other variables.

PEDA is not designed for, and does not pretend to be, a planning tool that will provide us with the exact number of food-insecure people in a country under the conditions stated in the different scenarios. Agricultural production and availability of food are subject to unpredictable market evolutions and climatic conditions, and it is difficult to make accurate medium- to long-term projections of the availability of food for consumption.

Moreover, the data as they are used, consist of too much estimation. What is important in the outputs and answers given by PEDA is the direction and magnitude of the relationships between the variables considered. These are perfectly illustrated by the model, without the pretension of precision.

Annex I. Initial values of population parameters used in the PEDA prototype for Zambia

Sub-groups	TFR	LEAB		EDUC	
		Females	Males	Females	Males
Urban, literate, food secure	5	50	48	-	-
Urban, literate, food insecure	5	42	40	-	-
Urban, illiterate, food secure	6	49	47	0.44	0.49
Urban, illiterate, food insecure	5	43	41	0.44	0.49
Rural, literate, food secure	5.6	49	47	-	-
Rural, literate, food insecure	5.5	42	40	-	-
Rural, illiterate, food secure	7	49	47	0.33	0.33
Rural, illiterate, food insecure	6.6	41	38	0.33	0.33