ROYAL ACADEMY FOR OVERSEAS SCIENCES
&
ROYAL ACADEMIES FOR SCIENCE AND THE ARTS OF BELGIUM:
NATIONAL COMMITTEE FOR BIOLOGICAL SCIENCES

NUTRITION AND FOOD PRODUCTION IN THE CONGO BASIN

Guest Editors: J. RAMMELOO, B. VAN DE VIJVER & P. GOYENS

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Koninklijke Vlaamse Academie van België
voor Wetenschappen en Kunsten

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International Conference

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FOREWORD

Nutrition is a universal human right. Population growth and a higher demand for food, together with a changing nutrition pattern and an increasing demand for animal protein, cause an ever-growing demand for arable land and are at the basis of an increasing pressure on the environment at a global level. Besides, industrialization in some places occupies large areas, resulting in loss of cultivated surface. But massive pollution by industry can also cause loss of productivity or even loss of arable surface. These phenomena negatively influence the global ecosystem and global climate, as well as the level of biodiversity.

The aim of this two-day conference, jointly organized by the "Environment and Development" Commission of the Royal Academy for Overseas Sciences and the National Committee for Biological Sciences of the Royal Academies for Science and the Arts of Belgium, was to highlight a number of topics related to nutrition, the demand for food, food production and biodiversity.

The scientific committee of the conference aimed at scrutinizing these phenomena in a region with a high level of biodiversity. Hence, the choice for the Congo Basin, which comprises for a large part, but not exclusively, the tropical rain forest region. The following countries are wholly or partially part of the Congo Basin: South-East Cameroon, the southern and central zones of the Central African Republic, Equatorial Guinea, Gabon, the Republic of Congo, the largest part of the Democratic Republic of the Congo and parts of Angola, Burundi, Rwanda, Tanzania, Zambia and South Sudan.

Another reason for having selected the Congo Basin is that it is also a particularly vulnerable area. Indeed, this region is characterized by:

— a very rapid population growth: the annual growth rate is 2.5 to 2.9 %; 50 % of the population are less than 20 years old;
— rapid urbanization: the annual growth of the urban population is 3.9 to 4.0 %; however, 65 % of the population still live in rural, sometimes very isolated areas;
— educational deficits and insufficient investment in human capital;
— technological deficits, e.g., deficient agricultural technology, characterized by low fertilizer use, low yields, erosion, ...
— deficient infrastructures;
— deficient "legal frame";

— political instability, chronic insecurity and conflicts, and population displacements;
— extreme poverty, deficient basic health and social services.

The conference, attended by more than 120 participants, brought together scientists both from the North and the South, with very diverse backgrounds: epidemiologists, bioengineers, veterinarians, lawyers, sociologists, economists, agricultural experts, health experts, ...

A very large number of topics was dealt with and discussed during the oral presentations and poster sessions, highlighting not only the importance of the theme but also its extreme complexity, because of the many connections and the continuous interplay between local processes, such as local food production, and processes occurring at a higher, national or regional level, for instance the integration of food markets. But interrelations exist at a global level as well: e.g. macroeconomic turbulences or climate change must also be taken into account.

The Scientific Committee of the conference are confident that the present volume of proceedings — full papers as well as poster presentations — will stimulate further discussion and relevant research for rational decision-making to improve living conditions and preserve biodiversity in the Congo Basin.

On behalf of the Royal Academy for Overseas Sciences and of the National Committee for Biological Sciences of the Royal Academies for Science and the Arts of Belgium, I would like to sincerely thank the FNRS for the financial support.

I warmly thank the members of the Academies involved and the secretariat of the Royal Academy for Overseas Sciences for their active participation and their help.

Prof. Dr Philippe GOYENS
Permanent Secretary
Royal Academy for Overseas Sciences

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Welcome Address

by

Dirk HUYGE*

Excellencies,
Permanent Secretary and Honorary Permanent Secretaries,
Consœurs and *Confrères*,
Colleagues,
Ladies and Gentlemen,

In my capacity as president of the Royal Academy for Overseas Sciences, I warmly welcome you to the international conference "Nutrition and Food Production in the Congo Basin".

The Royal Academy for Overseas Sciences, which is, together with the National Committee for Biological Sciences of the Royal Academies for Science and the Arts of Belgium, at the basis of today's event, was founded in 1928, albeit under another name. At that time, the area to which it devoted its attention was exclusively restricted to the Belgian Congo. Since then, it has greatly diversified its focus of interest to the whole of Africa and the rest of the overseas world. In this particular conference, the Academy concentrates on the Congo Basin rainforest, which is a broader geographical area than the one to which its name has traditionally been attached.

Basically, our Academy is a learned society grouping scientists from diverse disciplines in the fields of human, natural, medical and technical sciences. That does not mean, however, that this beautiful, early 19th-century palace in which you find yourself today, is an academic hiding-place and an ivory tower retreat where, remote from worldly and practical affairs, we solely engage in lofty, intellectual considerations and discussions. Contributing to the progress of scientific knowledge about overseas regions remains

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a prime objective of the Academy, but it is not the only one. The Academy also aims at serving as a meeting place for communication between the North and the South. Additionally, it wishes to promote research and the dissemination of knowledge concerning overseas countries within those overseas countries themselves. As such, the Academy duly strives to engage with the living world.

The present conference, focussing on various topics dealing with nutrition and food production in the Congo Basin, is a perfect example of the Academy's higher aspirations. Nutrition is a universal human right and, therefore, a problem at a global level. Focussing on a local environment, this conference will hopefully set standards and determine ways to approach this issue that will have relevance for other areas with a high level of biodiversity far beyond Central Africa.

I wish you all an entertaining and extremely productive conference!

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Is the World facing a Global Food Crisis? And Africa? Setting the Scene. An Introduction to the Conference

by

Jan RAMMELOO*

The Overall Picture

There is a lot of concern about the ability to feed the growing world population, as exemplified by titles in the press, quotes on internet, international fora, conferences organized by learned societies, ... According to the 2012 UN world population prospects, a reasonable estimate is a world population counting 11 billion inhabitants in 2100 (Anonymous 1 2013).

Over 80 % of the increase in the projected overall population size, whether by 2050 or 2100, will be absorbed by Africa (Anonymous 2 2013).The population of Africa represents only one seventh of the world population, but in the last fifty years Africa has been the continent with the highest population growth rate. This growth rate, 2.34 %, is the double of the world's population growth rate and is one of the drivers of food import. In 2010, 40 % of Africa's population was under the age of 15.

The increase is not evenly distributed over the African continent, but Central Africa, the region covered by the Congo Basin, certainly belongs to the region with a fast growing population. The latest FAO estimates indicate a reduction of "global hunger" and that the Millennium Development Goal of halving the proportion of undernourished people in developing countries by 2015 is within reach. However, the progress in sub-Saharan Africa has been modest, the region being afflicted by natural disasters and conflict (Anonymous 3 2014).

* President of the "Environment and Development" Commission of the Royal Academy for Overseas Sciences; President of the National Committee for Biological Sciences.

In the Overall 2014 Global Food Security Ranking table, of the 109 countries ranked, the Democratic Republic of the Congo is classified last, with an index of 24.8/100, in strong contrast with the first ranked, the United States, with an index of 89.3/100 and Belgium at no. 14, with an index of 82.0/100 (Anonymous 4 2014). It must be noted, however, that the Republic of Congo has already improved its score with 2.6 points in 2014, compared to 2013.

The Role of Economic and Agricultural Growth in the Reduction of Poverty, Hunger and Malnutrition (Anonymous 5 2012)

Economic growth is directly linked to hunger and malnutrition, although it is not sufficient to reduce hunger and malnutrition. Only if the poorest can participate in the growth process and its benefits, an improvement is possible. This means that the poor must be involved in increased employment and income-earning opportunities and that the higher income must be used to improve diet, sanitation and health services. Governments from their side have to invest public revenues in services as education, public health, infrastructure and safety.

In a period of twenty years, between 1990 and 2010, an income increase of 2 %/year/*capita* was realized globally through economic growth. This was going hand in hand with an increase of the intake of 210 kcal/person/day (about 8 %) globally, according to the FAO statistics. However, the increase was the lowest in sub-Saharan Africa (less than 130 kcal/person/day).

Besides a higher worldwide dietary supply in these twenty years, there was also a shift in consumption pattern. Worldwide the shares of cereals, roots and tubers declined, whereas the shares of fruits, vegetables and animal protein (including fish) increased. However, in sub-Saharan Africa the energy availability from cereals, roots and tubers increased, whereas the energy availability from fruit, vegetables and animal protein remained constant.

In Africa, the average minimal level of daily intake of fruit and vegetables is far below the recommended level by the WHO and the FAO, being 400 g of fruit and vegetables daily *per capita*. The daily intake has stagnated far below the recommendations (excluding potatoes and other starchy tubers). These low levels are thought to increase the risk of chronic diseases by micronutrient deficiencies.

Participating in economic growth is not an evidence for the poor and undernourished because they lack education, or have poor education. Economic

growths attributed to the exploitation of natural resources, as minerals, are capital intensive, a process in which the poor can hardly participate. Only if state revenues from these capital-intensive sectors are used to help the poor by improving the rural infrastructure, health infrastructure, roads, ... undernourishment can be combatted.

Economic growth as a consequence of agricultural growth is in most countries better for the poor than economic growth resulting from capital-intensive activities. Globally, the highest number of poor live in rural areas and agricultural growth affects more directly the rural economy.

The importance of agriculture for national economies varies greatly from country to country. In some of the developing countries, agriculture accounts for more than 30 % in the economic activity, whereas in industrialized countries this activity is sometimes responsible for not more than 2 % of the economic activity. The economies in sub-Saharan Africa are mostly agriculture-based and agriculture can thus contribute significantly to economic growth. As agriculture is concentrated in rural areas, it can contribute significantly to poverty reduction in these areas, which directly links to a better food situation. In countries with primarily urban poverty, a productive rural agriculture helps to keep food prices low, improving the purchasing capacity of the urban poor.

Reduction of poverty and the improvement of the nutritional situation are much more pronounced by the development of smallholder and labour-intensive agriculture than by mechanized agriculture.

Low agricultural growth is not pushing the rural non-farm economy. Rural households tend to shift to survival strategies. Growth in agriculture has to go hand in hand with improved communication with urban areas to be really beneficial for economic growth. In regions with a high population growth, the population increase cannot by absorbed by agriculture solely. Many poor African countries lack the basic agricultural infrastructure, or the infrastructure is degraded. Countries need to develop policies to improve the rural infrastructure so that farmers can be confident that their produce will reach the markets and will be bought. In sub-Saharan Africa less than 17 % of the roads are properly paved. If badly equipped harbours are added to the bad infrastructure of a country, productive regions are cut off the national and international markets.

Human diseases as HIV/AIDS, malaria and cholera hinder the efficiency of agricultural workforce and reduce productivity. Human diseases can influence trade balances because shipments can be refused for years from countries with disease outbreaks.

Importance of Agricultural Education (MAGUIRE C. J. 2000)

In poor, often isolated rural areas, technical knowledge mostly lacks. Literacy and education need to reach these areas in order to get a better organization and development of agriculture and food production. Agricultural education is very important to develop smallholders' food production. Mechanization, however, will often encounter a number of limitations due to small plot surfaces. Rural employment in agriculture has, however, a number of weaknesses. Employment is often highly informal, poorly organized, with gender-based and age-based inequalities. The social protection is limited. These weaknesses can be partly overcome by a better education.

Political Stability

Post-independence politics have been marked by numerous internal conflicts. It does not need an explanation that under war circumstances agriculture and agricultural development and food production cannot thrive in a well-balanced manner. Mostly, international food aid did not use the production capacity in Africa itself, because of the weak organizational structure, political uncertainties, and the inability to respond on short notice to the demand of often important food quantities.

Access to Crop Varieties

Access to crop varieties adapted to the local environment is another burden to sub-Saharan agriculture. For example, between 1960 and 2008, world maize yields doubled from 2.5 to more than 5 tons per hectare (in developed countries up to 8.6 tons per hectare), while in Africa yields stayed at less than 2 tons per hectare. And maize is only one example of the non-increasing yields (http://old.iita.org/cms/details/maize_project_details.aspx?zoneid=63&articleid=273). Agricultural research and crop selection programmes are only very weakly developed or even nearly absent in the Congo Basin area.

Collecting from the Wild

In rural areas collecting from the wild is putting a very high pressure on some species and ecosystems. Some plants, as *Gnetum africanum* for

example (http://www.fao.org/docrep/ARTICLE/WFC/XII/0671-B5.HTM), have completely disappeared over large areas due to wild collecting of the leaves. It will be imperative to select and domesticate a number of species that belong to the traditional food of the rural population. Picking mushrooms is part of most African cultures (http://www.fao.org/docrep/007/y5489e/y5489e00.htm). It has, however, not a destructive effect on the natural vegetation. Income generated by mushroom picking is for a number of vegetation types (*e.g.*, miombo woodland) in the long run higher than the income generated by firewood cutting.

Bush meat is a major problem in a number of regions due to the large amounts collected. As long as it will not be possible to offer animal protein from agricultural origin at a price lower than the cost of bush meat, the wild collected meat trade will remain a severe threat to biodiversity and to the functioning of a number of ecosystems (http://www.huffingtonpost.com/2013/03/20/bushmeat-hunting-africa_n_2915460.html).

Soil Condition

Low yields are partly explained by land degradation due to a continuous depletion of soil nutrients. Activities on new land only hold short-lived benefits. Soil erosion and neglecting soil conservation techniques do the rest (http://www.slideshare.net/carriebking/soil-erosion-in-africa-5865983). In reversing soil degradation, the use of fertilizer can help, but in many African countries the use remains very low compared to other developing regions of the world.

Suitable Agricultural Land and Land Availability

Despite the potential suitable land for agriculture, the amount of arable land *per capita* has declined over time. On the one hand, the population increase puts pressure on the availability of arable land; on the other hand, policies aiming at expanding arable land lack or seem to have failed. Ownership problems and the lack of transparency in enforcing ownership claims are a burden. African governments being unable to solve the problems of land issues are not in a good position to attract foreign or local investments to increase food production.

Notwithstanding local policy, a phenomenon of increasing importance is the fact that a number of foreign countries are in search of large areas of

suitable agricultural land in order to produce cash crops and to produce food, often in order to cover up future food needs, apparently not necessarily meant for and devoted to Africa.

Pests and Diseases

Smallholders' agriculture mostly lacks access to agrochemicals and lacks the knowledge of integrated pest control and pest management. The use of animal vaccines remains quite limited on the African continent as a whole (http://www.spipm.cgiar.org/c/document_library/get_file?p_l_id=17828&-folderId=18430&name=DLFE-76.pdf).

Post-harvest Infrastructure

Storage facilities, be it dry storage or cold storage, are often inadequate. Developing a cold chain is often impossible, but not a luxury under the often difficult climatic conditions. Hygienic conditions of slaughterhouses mostly do not stand the international standards. Packaging facilities mostly need improvement or simply need to be developed. Even storing food from one growth season to another can be problematic in rural areas, the harvest being prone to attack by animal life and fungi (http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/04/03/000158349_20140403104305/Rendered/PDF/WPS6831.pdf).

Climate Change (Anonymous 6 2014)

In some parts of Africa, climate changes have already contributed to disasters, especially by droughts or desertification, or have influenced the spread of animal diseases (rift valley fever in East Africa, avian influenza in poultry in West Africa, rinderpest, foot and mouth diseases).

Food Losses and Waste (Gustavsson *et al.* 2011)

Contrary to the developed world, the loss of food at consumers level is very weak. In the western world (Europe and North America), food waste at

consumers level is estimated at 95 to 115 kg/year/*capita*. In developing countries, like in sub-Saharan Africa, the amount is 10 to 15 times lower. In sub-Saharan Africa, consumers eat what they can get as food, even if the quality does not fit the western standards.

Food Importation (RAKOTOARISOA *et al.* 2011)

The import of food consists primarily of basic foodstuffs. Thus, food import is important to ensure food security. In African countries with a relatively strong industry, or having financial income through export of minerals or oil, import can be cheaper than producing the food in the country itself. Countries like the Democratic Republic of the Congo are net food importers. For countries lacking foreign currency reserves, persistent food imports create a problem by removing funds for fundamental developments, and in the meanwhile not solving their problem of food insecurity. FAO figures show that in 2007 only one third (19 of 53) of the countries of sub-Saharan Africa had enough agricultural export revenues, mainly through export of cash crops, to pay their food import bills. It means that most of the countries had to withdraw money from other sources than agricultural export to pay the food import bills, or had to live from donations, in order to guarantee food security.

The FAO has clustered African countries of sub-Saharan Africa, based on a number of variables. This clustering showed, as a general picture, that the richer the country, the more food they import, the more fertilizer they use, and the higher their yields. The low-income countries, hosting more than two-thirds of the African population, account for only 40 % of the total net food import.

Not only intra-Africa policies have influenced the poor growth of the agricultural production, also foreign agricultural policies are responsible for it. High subsidies from the OECD (Convention on the Organization for Economic Co-operation and Development) have kept the price for the main food products low. The dumping of agricultural products, such as the surpluses in grain and poultry meat from developed countries, has depressed market prices. Food aid plays an important role in Africa's food market but influences the local prices and thus the local production. There is much debate going on whether food aid, besides emergency assistance, is not making countries dependant by distorting local markets.

Between 1980 and 2007, the total net food import for Africa, as a continent, grew about 3.4 % per year, whereas the population growth was about 2.3 % annually. This means that, for the continent globally, population growth had been the main driver for food import and that *per capita* the food import only grew with 0.8 % yearly. In that period, the consumption pattern, as to which kind of food is consumed, had hardly changed. FAO data indicate that the production of roots, such as cassava, had raised in sub-Saharan Africa, which helps to explain why food imports *per capita* had increased but slowly and had stagnated.

Food Exportation

Africa's food exports have not increased much, certainly not if compared with the food imports. The products have not been very diversified if compared to the exports in the seventies of last century, being coffee, cocoa, tea, spices, ... Only some countries, like Kenya, export non-traditional products such as flowers, semi-processed fruits and vegetables. These products became the backbone of their agricultural exports.

Within Africa cereals have been exported, but mostly between African countries themselves.

REFERENCES

Anonymous 1. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat [2013]. World Population Prospects: The 2012 revision. — New York, United Nations.

Anonymous 2. Explaining differences in the projected populations between the 2012 and 2010 Revisions of World Population Prospects: The role of fertility in Africa. Population Facts 2013/10. — United Nations, Department of Economic and Social Affairs, Population division.

Anonymous 3. Food and Agriculture Organization of the United Nations 2014. The State of Food Insecurity in the world (SOFI). — Rome, FAO.

Anonymous 4. The Economist Intelligence Unit Limited.

Anonymous 5. FAO, WFP & IFAD 2012. The state of food insecurity in the world, 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. — Rome, FAO, 85 pp.

Anonymous 6. Alliance for a Green Revolution in Africa (AGRA) 2014. Africa agriculture status report: Climate change and smallholder agriculture in sub-Saharan Africa. — Nairobi (Kenya), 216 pp.

GUSTAVSSON, J. *et al.* 2011. Global food losses and food waste. — Rome, Report published by the Food and Agriculture Organization of the United Nations, 29 pp.

MAGUIRE, C. J. 2000. Agricultural education in Africa: Managing change. — Rural Development Department, The World Bank, 16 pp.

RAKOTOARISOA, M. A., LAFRATE, M. & PASCHALI, M. 2011. Why has Africa become a net food importer? Explaining Africa agricultural and food trade deficits. — Rome, Trade and Markets division, Food and Agriculture Organization of the United Nations, 89 pp.

Human Aspects

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Estimating the Number of Malnourished Children in the Democratic Republic of the Congo: Potential from the AfriPop and CEDAT Databases

by

Catherine LINARD[*, **], Chiara ALTARE[***] & Debarati GUHA SAPIR[***]

KEYWORDS. — Spatial Demography; Democratic Republic of the Congo; Health Metrics; Malnutrition; Conflict-affected Region.

SUMMARY. — The Democratic Republic of the Congo (DRC) is a country where demographic and health information is scarce, particularly in areas with chronic insecurity. These are, however, the areas where population needs are the highest. In this paper, two freely available databases have been combined in order to estimate the number of children under five affected by acute malnutrition in the DRC. Geostatistical methods have been used to produce a predicted malnutrition map based on small-scale surveys conducted by humanitarian agencies and estimates of children at risk have been derived from high-resolution population maps. Results show that 41 % of the children are in a serious or critical nutritional situation in the DRC. This paper shows that combined analyses of different sources of data can provide key insights into populations on which information is scarce.

1. Introduction

Whilst high-income countries generally have extensive mapping resources and demographic data at their disposal, in low-income countries relevant data tend to be either lacking or of poor quality. In the Democratic Republic of the Congo (DRC), the last national census was undertaken in 1984, when the total population was about 30 million. Today, the United Nations estimate that 68 million people live in the DRC. The population growth rate is

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currently around 2.8 % per year and the DRC population is expected to double in the next thirty years (United Nations Population Division 2012). In addition to this high growth rate, population displacements are massive. Since the last census, the DRC has suffered from fifteen years of conflict, which forced thousands of people to displace and deprived millions of basic health and social services. According to the Central Emergency Respond Fund report in 2008, conflict has generated up to 1.35 million internally displaced persons (IDPs) in only three provinces, corroding the coping mechanisms of millions of people.

The major changes in population size and distribution occurring in the DRC undermine the fidelity of the population estimates derived from last censuses. Instability has also hindered the establishment of a national system that routinely collects demographic and health information. However, nationwide surveys such as the Multi Indicators Cluster Surveys or the Demographic and Health Surveys (DHS) were conducted quite regularly in the DRC (1995, 2001, 2007, 2010). Statistics extracted from national household surveys are more uncertain because of the relatively small sample sizes used (< 5 % of the total population for the DHS 2007), but have the important advantage of providing updated estimates.

National health statistics very often have low coverage from areas with chronic insecurity. These are, however, the areas where population needs are the highest and change rapidly as violence evolves. While nationwide household surveys provide crucial data for the long-term monitoring of a country's living conditions, their five-year frequency does not allow for a timely identification of population needs. But small-scale surveys conducted with a higher frequency by humanitarian agencies in their area of intervention can provide updated key information on population needs in between the major surveys. CEDAT [1]* is the global repository of nutrition and mortality surveys and serves as an essential source of nutritional, health and mortality data for rational decision-making in disaster situations (Centre for Research on the Epidemiology of Disasters 2013).

In many low-income countries, census population counts and nationwide surveys are only reported in large spatial units that limit their potential use for health metric derivation and resource allocation (LINARD & TATEM 2012). In the DRC, census data are aggregated at the administrative level 3 (Territoires) that divides the country in 188 administrative units with an average size of 12,500 km^2. However, any attempt to estimate the population affected

* The numbers in brackets [ ] refer to the notes p. 31.

by conflict requires reasonable information on the resident population in the area and for the time period considered. Ideally, population distributions and counts should therefore be resolved to higher levels of spatial detail than large regional estimates. Modelling techniques for the spatial reallocation of populations within census units have been developed based on satellite-derived land cover data (LINARD & TATEM 2012, LINARD *et al.* 2012). Comprehensive and contemporary subnational information on the demographic attributes of these populations were also combined in order to depict age and sex compositions at subnational scales (TATEM *et al.* 2013).

The objective of this paper is to estimate the number of children under five affected by acute malnutrition in the DRC by combining two existing databases: the CEDAT collection of survey data from emergency situations and the AfriPop detailed population maps. Combined analysis of different sources of data can provide key insights into populations on which information is scarce.

2. Data and Methods

2.1. NUTRITION DATA

Nutrition data have been obtained from survey reports compiled in CEDAT. These surveys are conducted by field organizations such as UN agencies, non-governmental organizations and Ministries of Health in their area of intervention. This usually corresponds to a health zone in the DRC. The surveys are population-based and use a two-stage cluster sampling methodology. Anthropometric measurements are conducted and nutritional indexes calculated. In emergency, weight-for-height is the most commonly used indicator as it indicates level of wasting: this reflects the short-term loss of weight. Global Acute Malnutrition (GAM) is defined as – 2 weight-for-height z-score [2] according to WHO standard population (WHO & UNICEF 2009). We have included in the analysis all available surveys undertaken in the DRC during the period 2008-2011. In total, we have used two hundred twenty-one data points. Data quality checks have been performed.

2.2. POPULATION DATA

The AfriPop project [3] has recently completed the construction of the 2010 and 2015 estimates of population distribution for continental Africa and Madagascar at approximately 100 m spatial resolution (LINARD *et al.* 2012).

A GIS-linked database of census and official population estimate data has been constructed, targeting the most recent and spatially detailed datasets available, given their importance in producing accurate mapping (LINARD *et al.* 2012). Land cover data have then been used to redistribute population counts within administrative units to map human population distributions at 100 m. Figure 1 shows the AfriPop population dataset for the DRC.

Data on subnational population compositions from the last twenty years have been obtained from a variety of sources to derive demographic maps from the AfriPop total population map. For the DRC, the most recent Demographic and Health Survey (DHS 2007) has been exploited to provide the

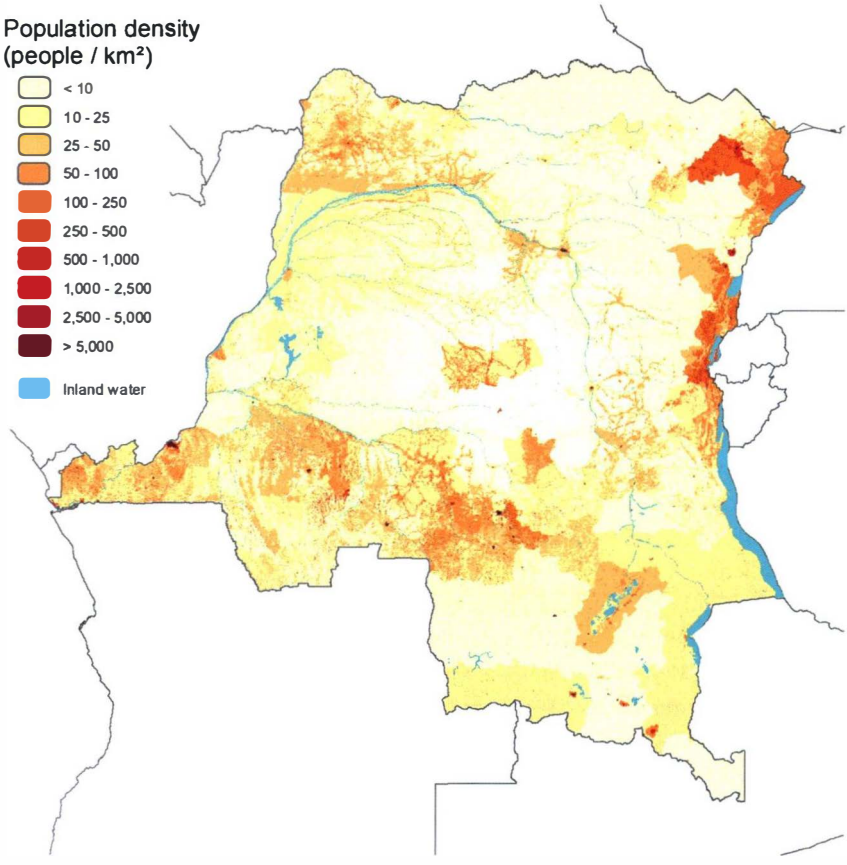

Fig. 1. — Population density in the DRC as estimated by the AfriPop database.

most contemporary and spatially detailed estimates as possible of age and sex proportions, given the constraints of its sampling framework. The derived age and sex subnational proportions have been used to adjust the existing AfriPop 2010 spatial population dataset, to produce estimates of the distribution of populations by sex and five-year age group across Africa in 2010. The datasets have then been adjusted to ensure that national population totals by age group matched those reported by the UN (United Nations Population Division 2012). For the analysis outlined in the remainder of this paper, the summation of the datasets representing males and females in the 0-5 years age group has been undertaken to produce a 2010 distribution dataset of children under five years old.

2.3. Estimating the Number of Children affected by Acute Malnutrition

The spatial dependence in survey data has first been examined using the 'ncf' package in the R statistical software (Bjornstad 2013). Geostatistical methods have then been used to spatially interpolate GAM values estimated at the two hundred twenty-one survey locations from the CEDAT database and produce a predicted GAM map for the DRC. Geostatistical methods make the assumption that the value at an unobserved location is a distance-weighted average of known neighbours. We have used a universal kriging method with quadratic drift (Cressie 1986) to predict GAM values at locations where measurements have not been made. The resulting GAM map has been overlaid with the map of children under five years old in order to derive estimates of children affected by malnutrition.

3. Results

Figure 2 shows the degree of spatial dependence in the GAM data from the CEDAT survey database. The average distance between CEDAT survey points in the DRC was 49 km. The positive index for distances below 500 km means that GAM values are spatially autocorrelated below this distance. Figure 3 presents the predicted GAM map resulting from the spatial interpolation. GAM values have been categorized according to WHO classification of emergency (World Health Organization 2000): acceptable (< 5 %), poor (from 5 to 9.9 %), serious (from 10 to 14.9 %) or critical (> 15 %).

According to our estimated map of GAM shown in figure 3, the eastern and northern regions of the DRC (South Kivu, North Kivu and Oriental

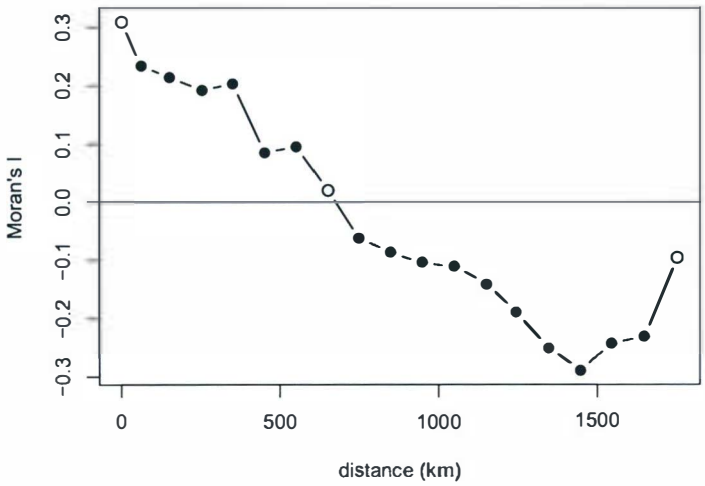

Fig. 2. — Spatial correlogram showing the spatial dependence of GAM values as measured by Moran's *I* at discrete distance classes. The zero-line (reference line) represents the region-wide similarity. The x-intercept represents the distance at which GAM values are no more similar than that expected by chance across the region (BJORNSTAD 2013).

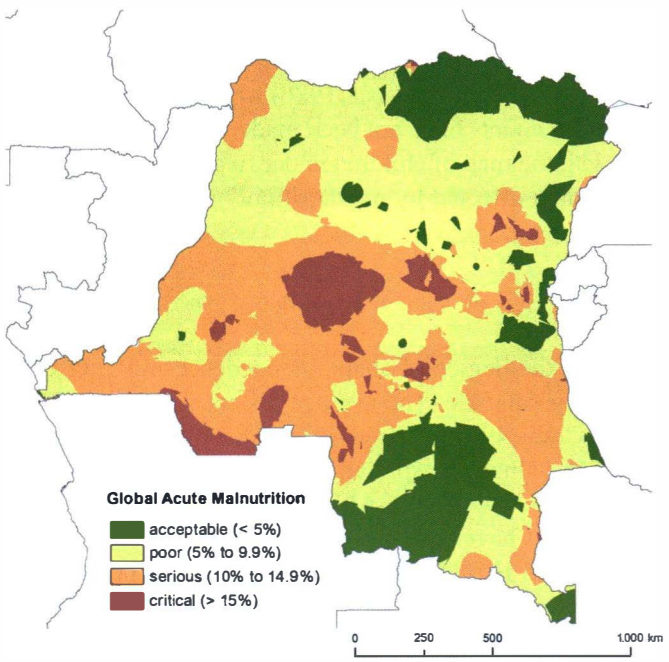

Fig. 3. — Results from the spatial interpolation of GAM values extracted from two hundred twenty-one survey locations from the CEDAT database (2008-2011 period). GAM values have been classified in four commonly used categories: acceptable (< 5 %), poor (from 5 to 9.9 %), serious (from 10 to 14.9 %) or critical (> 15 %).

Provinces) are mostly in an acceptable or poor nutritional situation. We can observe a high variation in GAM values in North and South Kivu. The nutrition level is acceptable in large areas of Katanga, while critical situations are predicted in some parts of the Kasai Province and in South Bandundu.

By combining the estimated GAM map with the under-five population surface, we can approximate the number of children affected by Global Acute Malnutrition. Figure 4 shows the estimated number of children under five in each Global Acute Malnutrition category. About 41 % of children under five are in the serious or critical categories, while nutritional conditions of less than one fifth are acceptable.

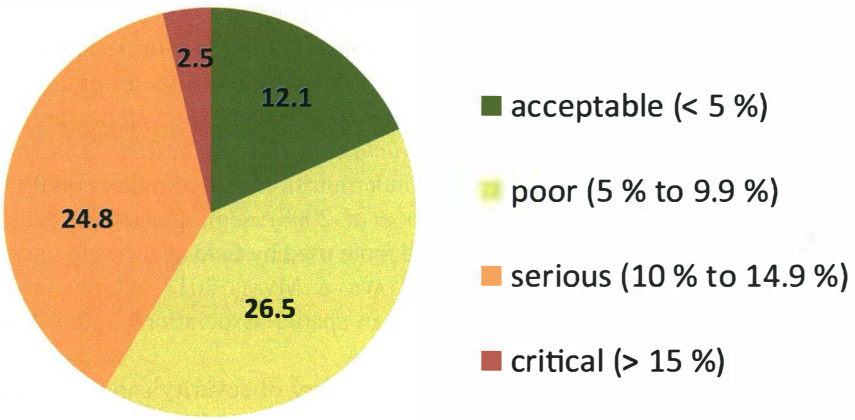

Fig. 4. — Number of children under five years old in each GAM category in the DRC (in millions).

4. Discussion

The DRC is a country where demographic information is scarce, both in spatial and in temporal resolution. The two databases we have presented here — CEDAT and AfriPop — aim at improving available demographic and health data for low-income and conflict-affected regions such as the DRC. The main objective of the AfriPop project is to provide spatially detailed population data. Its resulting map is particularly useful as denominator for the calculation of health metrics that vary across space. CEDAT provides updated information on population health status, including standardized health and nutrition indicators, between major surveys, thus with a better temporal resolution. In this paper we have shown the potential of combining these two datasets. Their different and complementary information allows us to estimate the number of children in an emergency situation in the DRC. It

also allows the identification of high-risk areas for targeting humanitarian help.

North and South Kivu reported acceptable and poor nutritional situations, despite being the regions mostly affected by conflict. The presence of nutrition programmes in these areas is probably responsible for the relatively good GAM values reported. Average GAM in locations with existing nutrition programmes is lower than in areas without nutrition programmes. At the same time, the high variability observed in the conflict-affected areas indicates that insecurity can worsen nutritional status as it hinders humanitarian interventions to reach all affected areas. Survey reports from Kasai and Bandundu, where critical situations are predicted, indicate that few or no nutrition programmes exist in these regions and that water and sanitation conditions are poor. In Kasai, few people are involved in agriculture because mining is a more attractive employment alternative (KANDALA *et al.* 2011) and income therefore largely depends on the market price of diamonds. High poverty prevalence among Bandudu's population (*Institut national de la statistique de la RDC* 2004) can explain the poor nutritional situation. Undernutrition is a complex condition that can be due to multiple factors (BLACK *et al.* 2008): semi-quantitative causal analyses at community level are more and more used by field agencies to understand the main causes of malnutrition (NYAWO & MYATT 2012, RATNAYAKE *et al.* 2013). Our analysis provides insights in spatial associations, rather than identifying causes.

Estimating the number of children by category of severity can contribute to a more evidence-based allocation of development and humanitarian aid. Absolute numbers are necessary to estimate the required financial and in-kind resources to feed people in need. Yet, uncertainties are associated with our estimates. Firstly, population estimates are based on the 1984 census and on DHS 2007: the availability of updated population data would allow for more precise geographical distribution of malnourished children. Secondly, nutrition data cover the period 2008-2011 and are patchy: increased coverage and availability of recent nutrition surveys would provide a more updated picture of the situation. Thirdly, population displacement due to insecurity continues to occur in eastern DRC, therefore increasing the uncertainty about numbers and location of malnourished children.

Detailed, spatially disaggregated and standardized population data are essential resources in the assessment of the number of impacted people for planning health and food service delivery and for decision-making processes related to developmental or health issues. We have shown here that various datasets exist to map the distribution of key vulnerable groups, and to study

demographic evolution through time. However, we have also outlined the importance of acknowledging, measuring and accounting for uncertainty in demographic datasets.

ACKNOWLEDGEMENTS

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NOTES

[1] Complex Emergency Database; Centre for Research on the Epidemiology of Disasters; Université catholique de Louvain.
[2] Oedema is included.
[3] AfriPop project: www.worldpop.org.uk

REFERENCES

BJORNSTAD, O. N. 2013. Package 'ncf': spatial nonparametric covariance functions. Available at: http://cran.r-project.org/web/packages/ncf/ncf.pdf

BLACK, R. E., ALLEN, L. H., BHUTTA, Z. A., CAULFIELD, L. E., DE ONIS, M., EZZATI, M., MATHERS, C. & RIVERA, J. 2008. Maternal and child undernutrition: global and regional exposures and health consequences. — *The Lancet*, **371** (9608): 243-260.

Centre for Research on the Epidemiology of Disasters 2013. Complex Emergency Database. Available at: www.cedat.be

CRESSIE, N. 1986. Kriging nonstationary data. — *Journal of the American Statistical Association*, **81** (395): 625-634.

Institut national de la statistique de la RDC 2004. Enquête 1-2-3, Kinshasa, INS.

KANDALA, N.-B., MADUNGU, T. P., EMINA, J. B., NZITA, K. P. & CAPPUCCIO, F. P. 2011. Malnutrition among children under the age of five in the Democratic Republic of Congo (DRC): does geographic location matter? — *BMC Public Health*, **11** (1): 261.

LINARD, C. & TATEM, A. J. 2012. Large-scale spatial population databases in infectious disease research. — *International Journal of Health Geographics*, **11** (1): 7.

LINARD, C., GILBERT, M., SNOW, R. W., NOOR, A. M. & TATEM, A. J. 2012. Population Distribution, Settlement Patterns and Accessibility across Africa in 2010. — PLoS ONE, **7** (2): e31743.

NYAWO, M. & MYATT, M. 2012. Causal analysis and the SQUEAC toolbox. — *Field Exchange*, **42**: 37-38.

RATNAYAKE, R., TESFAI, C. & MYATT, M. 2013. Determining predictors for severe acute malnutrition: Causal analysis within a SQUEAC assessment in Chad. — *Field Exchange*, **45**: 23-25.

TATEM, A. J., GARCIA, A., SNOW, R. W., NOOR, A. M., GAUGHAN, A., GILBERT, M. & LINARD, C. 2013. Millennium development health metrics: where do Africa's children and women of childbearing age live? — *Population Health Metrics*, **11** (1): 11.

United Nations Population Division 2012. World Population Prospects: The 2012 Revision. New York, United Nations. Available at: http://esa.un.org/wpp/

WHO & UNICEF 2009. WHO child growth standards and the identification of severe acute malnutrition in infants and children. — Geneva, World Health Organization and UNICEF.

World Health Organization 2000. Manual on the management of nutrition in major emergencies. — Geneva, IFRC/UNHCR/WFP/WHO.

Physical Aspects

International Conference
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National Committee for Biological Sciences
Brussels, 30 September - 1 October, 2013
pp. 35-54.

Soil Resources in the Congo Basin: their Properties and Constraints for Food Production

by

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Geert BAERT** & Eric VAN RANST***

KEYWORDS. — Congo Basin; Soil Characteristics; Soil Constraints; Food Production.

SUMMARY. — The Congo Basin, with a total area of about 3,822 000 km^2 and a population exceeding 90 million people, has generally lagged behind in agricultural development. The purpose of this paper is to describe the different soil types in the Congo Basin, their major constraints, the actual utilization types, their management and the impact of land use on food production. In the Congo Basin, 65 % of the population lives in rural areas and the majority is directly involved in agriculture. Food production requires suitable soils for crop cultivation; however, suitable soils for agricultural production are limited in the Congo Basin. Sustainable food production can partly be attained if soil characteristics and constraints are well understood.

1. Introduction

The Congo Basin forests support the livelihoods of more than 90 million people. A large part of this population is indigenous. In addition to these inhabitants, many others directly or indirectly rely on the forest for fuel, food, medicines and other non-timber products. For the Congo Basin's population, the forest is a major source of food. The contribution of forests to food

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security is very often overlooked, but rural communities in the Congo Basin get a significant portion of protein and fats in their diets.

Land-use changes influence the fertility of the soil. They mostly focus on deforestation, cropland expansion, dry land degradation, urbanization, pasture expansion and agricultural intensification. In tropical regions, forests are cleared for the expansion of cropland, wood extraction or infrastructure expansion. Croplands expanded by 50 % during the 20th century, from roughly 1,200 million ha in 1900 to 1,800 million ha in 1990. There are several interacting drivers for land-cover change but the exponential growth in human population is important. Currently, 95 % of the population growth takes place in tropical regions and soil fertility in these regions is affected by rapid land-use changes. The effects of deforestation and grassland conversions as well as agricultural intensification have been fairly well-documented but the spatial and temporal effects of soil fertility change and its interaction with land-use change remains to be investigated.

The purpose of this paper is to describe, through a literature review, the different soil types in the Congo Basin, their major constraints, the actual utilization types, their management and the impact of land use on food production. Most soils in the Congo Basin may have one or more limitations for food production. The number and severity of problems increase rapidly if a soil has been left without cover, has been eroded, burned or compacted by machinery.

2. Congo Basin Characteristics

Although agriculture is the main economic activity in tropical regions, the proportion of cultivated land is virtually the same as in the temperate regions: about 10 %. There is a tremendous potential for expanding agricultural output in the Congo Basin by bringing new land into production with a reasonable degree of expected success. One of the factors presently limiting the utilization of tropical areas suited for crop production is the inadequate knowledge on how to manage the highly weathered soils presently under rainforest or savannah vegetation.

The proper management of soils in the Congo Basin is considered one of the critical components in the worldwide race between food production and population growth. In spite of the voluminous literature, comprehensive knowledge of the characteristics of soils in the Congo Basin is still quite limited (NACHTERGAELE & VAN RANST 2003). One of the reasons for this lack

of integrated knowledge has been the development of strong local biases by full-time tropical soil scientists working only in a specific area or country. The lack of a common language has thus impeded the transfer of many important management findings from one area to another.

3. Overview of Soil Information

In most African countries, with the exception of a few countries such as Kenya, detailed information on the soil resources is generally inadequate for most developmental purposes. Farm-level information and detailed soil maps do not exist. The link of this to other socio-economic constraints, including land tilling and availability of capital for land-management investments, provides the explanation for the lack of progress in poverty alleviation and food security in sub-Saharan Africa (CLEAVER & SCHREIBER 1994). Large gaps in soil information persist in many African countries. In the case of the DR Congo for example, considerable attention was also given to soil and vegetation mapping. From 1945 till 1960, around 15 % of the territory of Congo was mapped by the Belgian soil survey team of INEAC, at scales ranging from detailed (1:10 000) to reconnaissance level (1:200 000 - 1:500 000) (SYS 1960, Baert *et al.* 2009, Baert *et al.* 2013) (fig. 1). The Belgian teams working under INEAC developed their own legend for the soil maps — the INEAC Soil Classification —, the insights of which were at the base of diagnostic horizons adopted in Soil Taxonomy and in WRB (World Reference Base) to accommodate soils of the tropics. Besides the INEAC soil surveys, several other soil surveys were carried out after the independence by the Laboratory of Soil Science of Ghent University at detailed level for agricultural purposes (BAERT *et al.* 2013), *e.g.*:

— Kaniama-Kasese (Katanga): evaluation for maize;
— Lubilashi (Katanga), Fiwa (Equator), Mushie Pentane (Bandundu) and Luiza (Oriental Kasai): evaluation for sugarcane;
— Katale (North Kivu): evaluation for coffee.

4. Soil Information and Major Soil Types in the Congo Basin

The Soil and Terrain database of Central Africa (SOTERCAF, version 1.0) was compiled at scale 1:2 million for DR Congo and at scale 1:1 million for

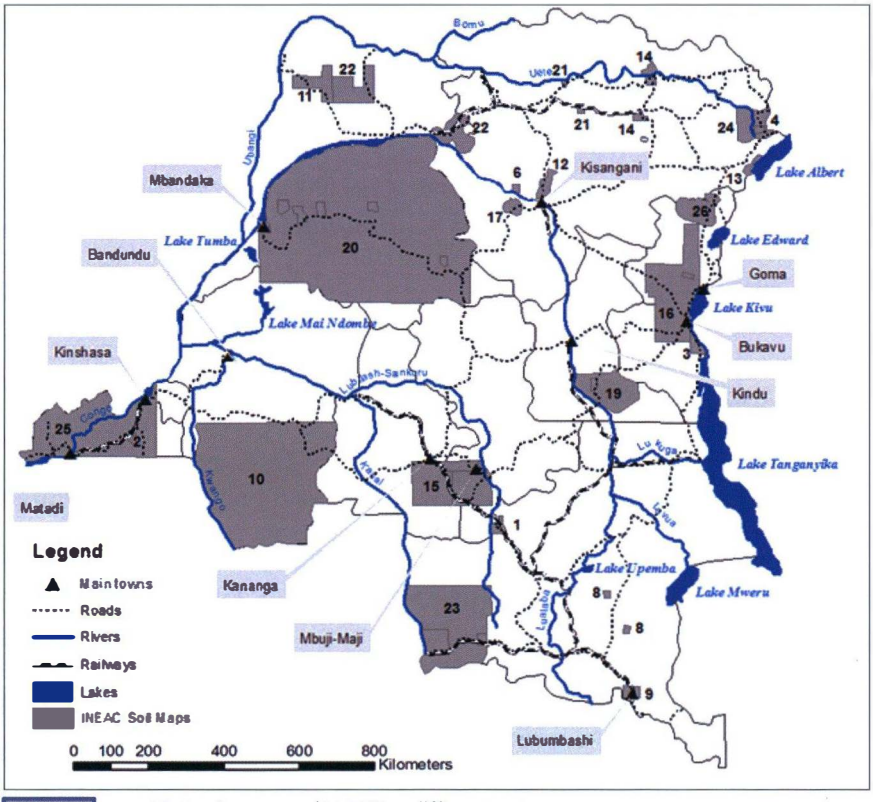

Fig. 1. — Mapped area soil surveys in DR Congo (INEAC & UGent) (BAERT *et al.* 2013).

Rwanda and Burundi. The SOTERCAF compilation has been a joint collaboration of the Soil Science Laboratory of Ghent University (Belgium) and ISRIC (World Soil Information, Wageningen) - FAO (VAN ENGELEN *et al.* 2006, NGONGO *et al.* 2009).

The distribution of soils in the Congo Basin is illustrated in figure 2, whereas their occurrence in the Congo Basin countries is presented in table 1. It is obvious that the soils of this region show a considerable diversity as a result of major differences in moisture regime, lithology, age, degree of weathering of parent materials, relief and elevation above sea level (VAN WAMBEKE 1989).

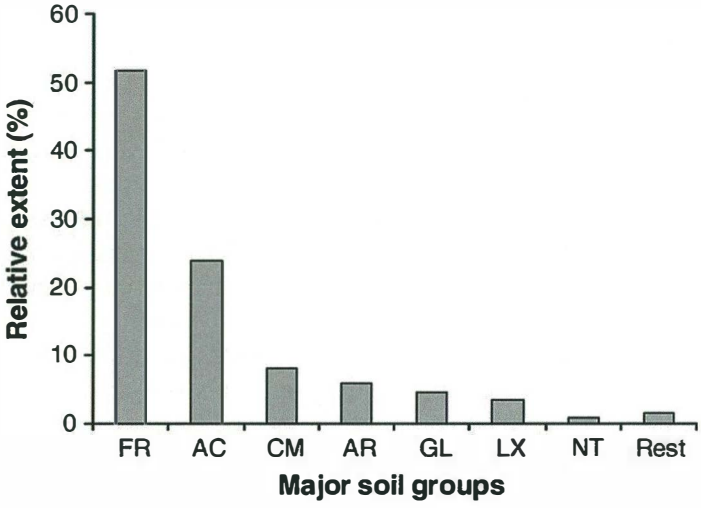

Fig. 2. — Proportion of major soil groups (FAO-UNESCO-ISRIC 1988) in Central Africa (FR = Ferralsols; AC = Acrisols; CM = Cambisols; AR = Arenosols; GL = Gleysols; LX = Lixisols; NT = Nitosols; Rest = all other units (covering 0.5 % of the region)).

Table 1
Major soil types in some countries of the Congo Basin
(FAO-UNESCO-ISRIC 1988, JONES *et al.* 2013)

	Central African Republic	CONGO	CAMEROON	GABON	DR CONGO
1	XANTHIC FERRALSOLS	RHODIC FERRALSOLS	XANTHIC FERRALSOLS	XANTHIC FERRAL-SOLS	HAPLIC FERRALSOLS
2	RHODIC NITISOLS	XANTHIC FERRALSOLS	RHODIC FERRALSOLS	FERRALIC ARENOSOLS	RHODIC FERRALSOLS
3	HUMIC FERRALSOLS	EUTRIC GLEYSOLS	RHODIC NITISOLS	DYSTRIC FLUVISOLS	FERRALIC ARENOSOLS
4	EUTRIC VERTISOLS	HUMIC CAMBISOLS	DYSTRIC GLEYSOLS	DYSTRIC GLEYSOLS	EUTRIC GLEYSOLS
5	EUTRIC GLEYSOLS		EUTRIC GLEYSOLS	RHODIC NITISOLS	HAPLIC ACRISOLS
6	DYSTRIC REGOSOLS		EUTRIC VERTISOLS	HUMIC CAMBISOLS	FERRALIC CAMBISOLS
7			DYSTRIC REGOSOLS		HAPLIC NITISOLS

Figure 2 shows that highly weathered soils, especially Ferralsols and Acrisols, are represented to a higher extent. This relative extent can be illustrated with the case of the DR Congo, Rwanda and Burundi as shown in the SOTERCAF soil map (VAN ENGELEN *et al.* 2006). The main reference soil groups in the DR Congo, Rwanda and Burundi Soil Map are Ferralsols (Dominance of kaolinite and sesquioxides), Acrisols (low base status, low-activity clay), Cambisols (moderately developed soils), Arenosols (sandy soils), Gleysols (groundwater-affected soils), Histosols (soils with thick organic layers), Lixisols (high base status, low-activity clay) and Nitisols (low-activity clay, P fixation, strongly structured), covering some 99 % of the region. The main soil units are haplic Ferralsols (FRh, about 29 %), haplic Acrisols (ACh, ~23 %), xanthic Ferralsols (FRx, ~16 %), umbric Ferralsols (~5 %), eutric Gleysols (~4 %), ferralic Cambisols (CMo, ~3 %), haplic Lixisols (LXh, ~3 %), ferralic Arenosols (ARo, ~2 %), dystric Cambisols (CMd, ~2 %), rhodic Ferralsols (FRr, ~2 %) and haplic Arenosols (ARh, ~2 %). These units cover over 90 % of the Congo Basin. Qualifiers (xanthic, rhodic, haplic, ...) are associated with Reference Soil Group (Prefix or Suffix) and reflect diagnostic proprieties, materials, characteristics such as colour, base status and other chemical and physical properties. Some explanations of the most common qualifiers that are added to the name of the Reference Soil Groups in the Congo Basin are:

— Xanthic: having a *ferralic* horizon that has a subhorizon, 30 cm or more thick within 150 cm of the soil surface, a Munsell hue of 7.5 YR or yellower and a value, moist, of 4 or more and a chroma, moist, of 5 or more;
— Dystric: having a base saturation (by 1 *M* NH4OAc) of less than 50 % in the major part between 20 and 100 cm from the soil surface or between 20 cm and *continuous rock* or a cemented or indurated layer, or, in *Leptosols*, in a layer, 5 cm or more thick, directly above *continuous rock*;
— Eutric: having a base saturation (by 1 *M* NH4OAc) of 50 % or more in the major part between 20 and 100 cm from the soil surface or between 20 cm and continuous rock or a cemented or indurated layer;
— Ferralic: having ferralic properties in at least some layer starting within 100 cm of the soil surface;
— Gleyic: having within 100 cm of the mineral soil surface in some parts *reducing conditions*;
— Haplic: having a typical expression of certain features (typical in the sense that there is no further or meaningful characterization) and only used if none of the preceding qualifiers applies;

— Humic: having the following organic carbon contents in the fine earth fraction as a weighted average in *Ferralsols* and *Nitisols*, 1.4 % or more to a depth of 100 cm from the mineral soil surface;
— Rhodic: having within 150 cm of the soil surface a subsurface layer, 30 cm or more thick, with a Munsell hue redder than 5 YR (3.5 YR or redder), a value, moist, of less than 3.5 and a value, dry, no more than one unit higher than the moist value.

The Reference Soil Group of the Ferralsols is dominant in the Congo Basin (fig. 2). Ferralsols are deep, intensively weathered soils. They have a deep solum, with a 'ferralic' subsurface horizon, reddish or yellowish in colour, and with diffuse or gradual horizon boundaries. These soils have generally a weak macrostructure and a strong microstructure ('pseudo-silt' and 'pseudo-sand'). Acrisols is the second most important Reference Soil Group in this region. These soils have a thin, brown surface horizon, particularly in regions with pronounced dry seasons; darker colours are found where periodic waterlogging retards mineralization of soil organic matter (SOM). The underlying lighter coloured, eluvial subsurface horizon has weakly developed structure elements and overlies a stronger coloured yellow to red 'argic' subsurface horizon. The structure of this sesquioxide-rich illuviation horizon is more stable than that of the eluviation horizon (DRIESSEN *et al.* 2001).

Knowledge and a good understanding of the main properties of these highly weathered soils (HWS) is of utmost importance for a rational management when these soils are used for agriculture.

5. Properties of the Highly Weathered Soils in the Congo Basin

5.1. MINERALOGICAL PROPERTIES

Ferralsols have mineralogical assemblages in which a few major constituents often make up as much as 90 % of the total contribution. Among these minerals are 1:1 layer silicates of the kaolin group, oxides of Fe, Al and Ti and some highly resistant minerals either inherited or transformed from the parent rock such as quartz, muscovite and probably Al-hydroxy-interlayered vermiculite (VAN RANST 1994, NGONGO *et al.* 2009). The simple and rather uniform clay mineral assemblage of the Ferralsols suggests an advanced stage of weathering. Acrisols have a somewhat similar

mineralogical composition, also dominated by low-activity clays (LAC), *i.e.* clays with a low cation exchange capacity (CEC less than 24 $cmol_c$ kg^{-1} clay).

5.2. Physical Properties

The texture of HWS of the Congo Basin is closely related to the nature of the parent rock and may vary from sandy clay loam on sandstones and quartzites to heavy clay on shales and basic rocks. A common characteristic is the low silt content. Large parts of the Congo Basin consist of fluvio-aelion deposits; soils on those materials predominantly have a loamy sand to sandy clay loam texture.

The Ferralsols, particularly in their undisturbed state, are renowned for their 'excellent physical' properties; this refers mainly to their good permeability to water and air, despite the generally high clay content. The average permeability of Ferralsols in the Congo Basin was observed to be about 14 cm h^{-1} in the surface layers and 6.5 cm h^{-1} in the subsoil. Thus, many Ferralsols are easily trafficable, even shortly after heavy rainfall. This is attributed to the strong aggregation which characterizes their microstructure. The stable microporosity can be explained by the formation of strong microaggregates (negatively charged clay surfaces combined with positively charged sesquioxide surfaces). Soils with 60 % or more clay 'feel loamy' and have similar pore space and mechanical properties as medium- or even light-textured soils. Yet, the macrostructure of these soils is generally weak, even in the ferralic horizon. This weakness of the macrostructure renders Ferralsols prone to compaction. However, because of the strong stability of individual aggregates, a rapid recovery of favourable physical conditions could be achieved with appropriate tillage management (El-Swaify 1980).

Acrisols have a weaker microstructure compared to Ferralsols and a massive macrostructure, particularly where the organic matter content of the surface soil is low, because of the uneven distribution of sesquioxides over the soil mass with low amounts residing in the surface horizons (Van Ranst 2004, Ngongo *et al.* 2009).

Ferralsols and Acrisols, both dominated by LAC, have a low available water content compared with soils characterized by high activity clays (HAC). This may represent serious limitations especially under seasonally dry climates (Van Ranst 2004, Nongo *et al.* 2009).

5.3. Chemical Properties

Due to the dominance of LAC, the HWS of the Congo Basin have large amounts of pH-dependent charge and can be considered as dominantly variable-charge systems. The variable-charge effect in these soils arises from the presence of organic matter (OM) and inorganic constituents having amphoteric surfaces, *e.g.*, Fe oxides and gibbsite. The edge face of the clay minerals present, kaolinite and muscovite, and probably complexes of Fe and Al with organic matter also have amphoteric surfaces (Van Ranst 1994).

The CEC (by 1M NH_4OAc, buffered to pH 7) of a ferralic horizon may by definition not be in excess of 16 $cmol_c\ kg^{-1}$ clay and the effective cation exchange capacity (sum of exchangeable base cations plus exchangeable acidity in 1M KCl) should be less than 12 $cmol_c\ kg^{-1}$ (FAO 2006). The CEC of the topsoil is almost entirely attributable to soil organic matter (SOM). The amount of OM immobilized in a rainforest varies from 150 to 300 t ha^{-1} of dry material containing 1.5 to 2 tonnes of mineral salts. The annual gain at the soil surface is estimated at about 15 t ha^{-1} dry material containing approximately 200 kg of nitrogen, 250 kg of mineral salts and 250 kg of silica. The OM content of a soil under rainforest is about 110 t ha^{-1}, which is seven times more than the annual gain (Van Ranst 2004).

Soil organic C is predicted to fall from 43 to 25 t ha^{-1} in fifteen years, with continuing inputs of 2 t ha^{-1} instead of 11 t ha^{-1} of C per year. These levels correspond approximately to humid tropical conditions changing from forest cover to arable crop production (Jenkinson 1990). A forest fallow in a shifting cultivation system is able to rebuild the original SOM level in about ten years. The most essential function of the fallow, the accumulation of mineral elements in the aerial parts of the plants, is also gradual but achieved in a later stage (tab. 2).

Table 2
Immobilization of mineral elements by a forest fallow at Yangambi (Sys 1979)

Year	**Dry material** (t ha^{-1})	**Immobilization of minerals** (kg ha^{-1})		
		N	**P**	**K**
2	20	190	22	160
5	112	570	32	420
8	153	580	35	670
18	173	700	108	820

The length of the fallow period depends on the quality of the soil and the fertility status at the moment the field was abandoned. In the Congo Basin, twelve to fifteen years of fallow is generally required for Ferralsols to regenerate the soil after a two-to-three years rotation including maize, rice, cassava and bananas (SYS 1979). On better soils, the length of fallow remains similar but the cropping period may be longer (five to six years).

The amount of nutrients stored in soils of the Congo Basin is mainly related to the SOM content and the production of OM by the vegetation. Under natural vegetation, the development of the humiferous topsoil is an expression of the soil fertility. The nitrogen (N) in SOM remains the most important source of N for crop production. The annual addition of fresh OM is about 15 t ha^{-1} under a tropical rainforest but may vary according to the development stage of secondary forest regrowth, from 3 to 15 t ha^{-1}. The annual decomposition rate of SOM varies from 2 to 5 % (average 4 %) under rainforest and is estimated at 1.2 % under savannah (SYS 1979).

In the Congo Basin it has been estimated that the first year of cultivation, the SOM, representing 10 000 kg ha^{-1} to a depth of 1 m, may supply as much as 400 kg ha^{-1} of available nitrogen per year. As cultivation continues and the organic nitrogen declines, the quantity of nitrogen becoming available each year declines. After some years of cultivation, the SOM becomes exhausted as a major source of available nitrogen, and, unless legumes are grown, the annual available nitrogen from natural supply processes comes chiefly from rain water and from non-symbiotic nitrogen fixation. The management of crop residues is an important factor in N-supply.

With an increasing degree of weathering, the total phosphorus (P) content of the soil decreases. Ferralsols contain around 200 ppm P, usually between 20 and 300 ppm, which is very low. In these soils the ratio C/P and N/P, which are good parameters for the availability of P, are 200-250 and 20-25 respectively, instead of 100-120 and ~10, considered as more optimal values. In HWS, containing high amounts of Fe oxides, the fraction of P which has not been leached is included mostly inside these compounds. Organic P is especially important in areas where P fertilizers are not available.

Loss of SOM through oxidation when the soils are cultivated or through erosion reduces the ability to supply N, P and S for crops. It also reduces the ability to retain cations in an available form. The HWS of the Congo Basin have limited amounts of base cations and the exchange complex has usually a certain amount of exchangeable Al, responsible for the acidic pH. This exchangeable Al affects the normal activity of the soil micro-organisms; in the first place rhizobium is affected. Normally, if exchangeable Al represents

30 % or more of the total exchangeable base cations content, no more development of rhizobium occurs; development of fungi may also be affected. At a certain concentration, exchangeable Al acts as a poison. The toxicity is considered to be indirect. Aluminium, being relatively immobile in the plant, could stop cell division of the termal root meristeme and the aerial grown buds. Aluminium precipitates P as aluminium phosphate in the rootcells preventing P-transportation in the plant. The acid HWS of the Congo Basin must be limed if acceptable yields of Al-sensitive crops have to be obtained. The purpose of this liming is primarily to neutralize the exchangeable Al, and this is normally accomplished by raising the pH to 5.5 or 6, in case Mn toxicity is suspected.

6. Suitability for Crop Production in the Congo Basin

Soil properties, including soil climate, provide some preliminary information to address soil quality. Soil quality is used here to indicate the ability of the soil to perform its function of sustaining agriculture under the current low-input system of agriculture in the Congo Basin. Low input implies that large-scale irrigation is absent, use of fertilizers, pest and weed control is minimal, and soil management does not require high-energy mechanized equipment. The low-potential lands have several major constraints, which are not easily corrected through management.

The unsustainable class of lands are lands which are considered to be fragile, easily degraded through management and, in general, not productive or not responding well to management. They are generally highly erodible and require very high investments for any kind of agriculture. High-potential lands are lands with some minor limitations. The medium- and low-potential lands have major constraints for low-input agriculture. Resource-poor farmers who live on these lands have high risks and generally the probability of crop failure is high to very high. The constraints include surface soil crusting, impermeable layers, soil acidity (specifically subsoil acidity) and high-risks water erosion.

The soil properties analysis and evaluation provide a first assessment of crops suitability. Much of the land within the Congo Basin is biophysically capable of supporting some type of sustainable agriculture system. Much of their sustainability is dependent on the extent of inputs to maintain soil quality. In many countries of the Congo Basin, though, application of costly inputs in order to achieve sustainability is not realistic. Expansion of low-input

agriculture systems on these soils is likely to result in soil degradation and loss of productivity. There is thus an urgent need to provide alternate options for a more equitable use of the soil resources until some form of capital-intensive systems can be implemented. Food security is becoming or is already of paramount concern in many of the Congo Basin nations. Traditional agriculture systems and declining "aid" imports may not supply the needs of a region which has some of the highest birth rates (KESSEBA 1993). A declining resource base will eventually contribute to civil unrest due to uncertain food supplies.

As the population growth and the demand for suitable agricultural land increases, there is need for a planned assessment of agricultural potential in the Congo Basin. Thus, soil resources, especially using small-scale regional maps and more detailed national and local assessments can provide better information for crop suitability. With socio-economic and other data layers, realistic national assessments and appropriate strategic plans can be developed.

Eleven types of soils (Land Units) were taken as the basis for the assessment of the agricultural potential in the Congo Basin. Soil characteristics (tab. 3) and qualities of those soils were matched with crop requirement of five major crops (Land Utilization Types (LUT): maize, rice, banana, cassava, oil palm), grown under rainfed conditions in the Congo Basin. Estimates were made, at Congo Basin level, of the suitability of soil for rainfed crop production, for each crop, divided into five classes: very suitable (S), suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N):

— Class S1 Highly Suitable: land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
— Class S2 Moderately Suitable: land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
— Class S3 Marginally Suitable: land having limitations which in aggregate are severe for sustained application of a given use and will reduce

productivity or benefits or increase required inputs in a way that this expenditure will be only marginally justified.

— Class N (N1= Currently Not Permanently / N2 = Not Suitable):
  - N1: land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
  - N2: land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

Except for S1 and N, all classes were subdivided in Land Suitability Subclasses depending on the type of limitation, *e.g.*, moisture deficiency, erosion hazard. Subclasses are indicated by lower-case letters with mnemonic significance, *e.g.*, S2m, S2e, S3me (m = water limitation, n = nutrients limitation, h = relative humidity limitation, w = flooding, u = insolation, r = root depth limitation, e = erosion risk). Examples are given in table 4. Soil characteristics are the key element in determining the productivity of the land and these differ widely in the Congo Basin as a result of different parent materials and pedogenesis. Steps undertaken for land suitability classification are:

1. For each land unit, decide which land qualities and land characteristics are "class-determining'" with respect to the requirements and limitations of the LUT(s);
2. For each land unit, complete tables (tab. 3) entering the appropriate values of the land qualities and land characteristics;
3. Match "critical limits" of each land-use requirement or limitation with the conditions found in the land unit to obtain a factor rating of s1, s2, s3, n1 or n2 for each combination of LUT and land unit (tab. 4 / fig. 3);
4. Combine individual "class-determining" factor ratings to obtain a tentative land suitability classification for each LUT on each land unit.

For the Congo Basin's soils, suitability classes have been defined mainly reflecting limitations of fertility, depth, drainage, moisture regime, temperature regime, etc. (tab. 4). The impact of the major limitations on the production of the considered crops in the Congo Basin is presented in figure 3.

Table 3
Soil characteristic levels affecting soil fertility (BAERT *et al.* 2009)

Land Units	pH	C	N	K	Ca	CEC	Al	P (Bray)	Depth
		%	%	$cmol_c\ kg^{-1}$ sol				$mg\ kg^{-1}$	cm
Haplic Acrisol	5.2	0.87	0.6	0.1	1.2	8.2			>100
Xanthic Ferralsol	4.9	0,6	0.3	0.05	0.4	4.1	0.8	1.5	>100
Gleyic Arenosol	4.3	0.31	0.02	0.07	0.35	3.8	1.2	2.1	>100
Haplic Ferralsol	5.9	0.7	0.12	0.25	2.2	4.5	-	-	>100
Eutric Regosol	4.7	0.8	0.2	0.1	1.9	3.1	-	-	=< 40
Haplic Lixisol	5.9	1.8	0.2	0.5	5.3	6.7	-	-	>100
Eutric Cambisol	6.1	2.3	0.23	0.9	7.2	10.8	-	-	=< 60
Rhodic Ferralsol	5.7	0.25	0.03	0.09	0.9	3	-	-	>100
Haplic Arenosol	5.3	0.4	0.02	0.2	0.6	2.5	-	-	>100
Plinthic Ferralsol	4.6	0.9	0.07	0.08	1.2	5	-	-	=<90
Gleyic Acrisol	5.9	0.22	0.06	0.12	3.5	5.8	-	-	>100 (gleyic)

Table 4
Soil suitability classes

Land Unit	Maize	Rice	Banana	Cassava	Oil Palm	Coffee
Haplic Acrisol	S3nhu	S2/S3nu	S3nhu	S2n	S2n	S2n
Xanthic Ferralsol	S3nhu	S3un	S3n	S2ne	S2nu	S2n
Gleyic Arenosol	N1nwhu	S3wnu	S3nw	N1wn	S3wnu	S3wn
Haplic Ferralsol	S3wnuh	S3nuw	S3nuw	S3nw	S2nw	S2nw
Eutric Regosol	S3nhur	S2/S3uwn	S3nw	S3wnu	S2nuw	S3wn
Haplic Lixisol	S2/S3nh	S2/S3nu	S2n	S2n	S2nur	S2n
Eutric Cambisol	S2nhr	S3run	S2rn	S2r	S2rn	S2r
Rhodic Ferralsol	S3nh	S2/S3 nu	S3n	S2n	S3nw	S2n
Haplic Arenosol	S3nh	S2/S3nu	S3n	S2n	S2/S3nu	S2n
Plinthic Ferralsol	S2/S3nc	S2un	S2n	S2n	S2/S3nu	S2n
Gleyic Acrisol	S3nhc	S3uer	S2rS2r	S2r	S2/S3ru	S2er

Good soil management helps to maintain and improve soil fertility while sustaining optimum crop yield over time (fig. 4).

Most of the soils in the Congo Basin are considered as moderately to marginally suitable, due to low fertility, high risk of erosion, moisture and temperature regimes. High content of Fe and Al oxides create the acidic soil property. Such soils fix high amounts of phosphates.

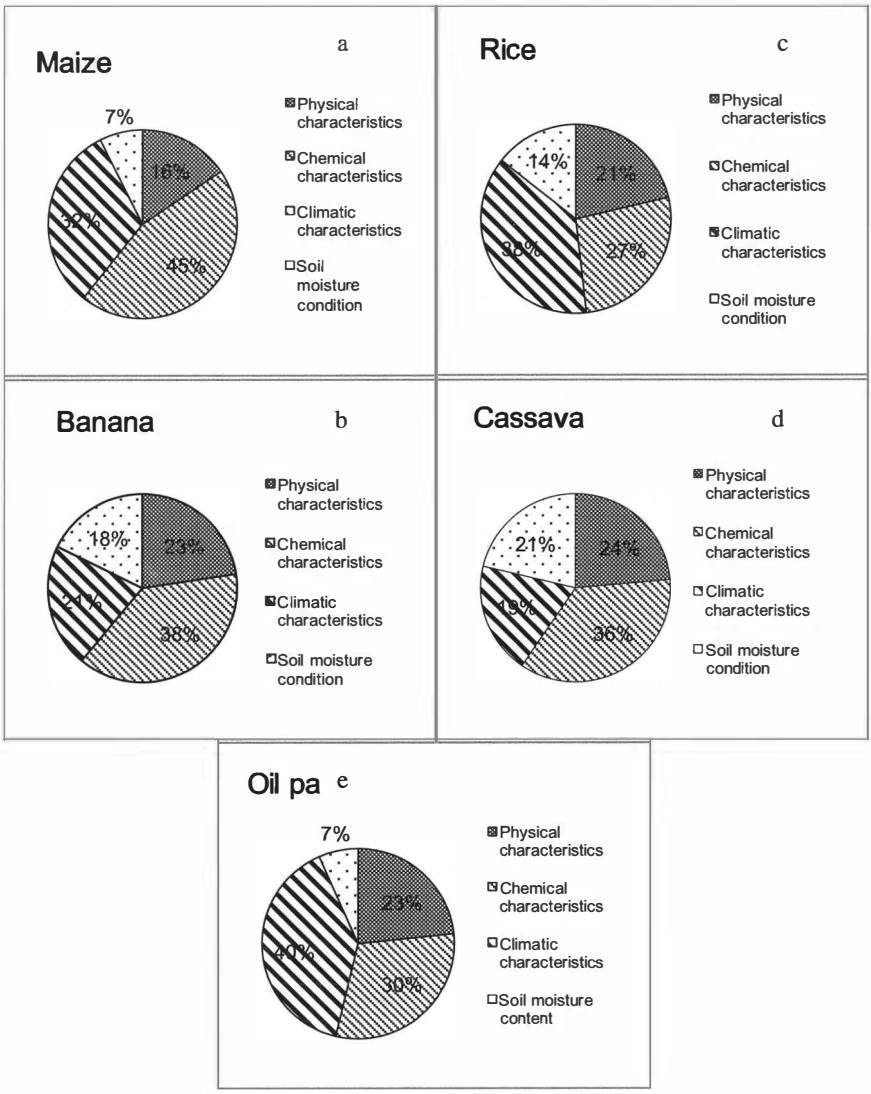

Fig. 3 (a, b, c, d, e). — Influence of each group of characteristics on the suitability class of the land utilization type.

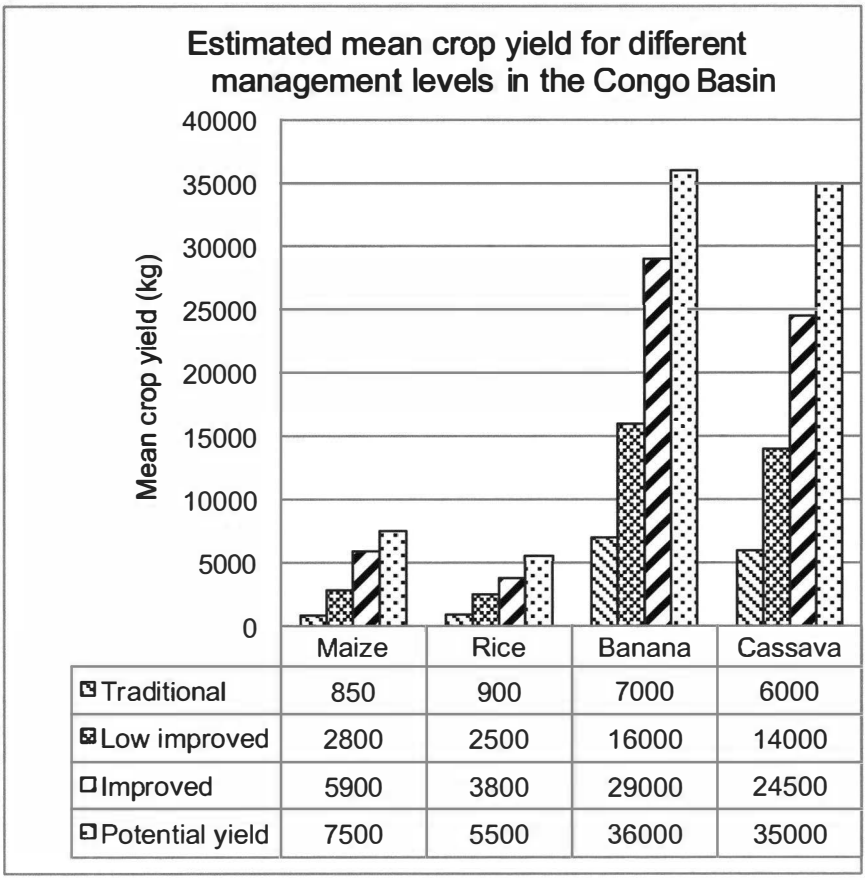

Fig. 4. — Estimated mean crop yield for different management levels in the Congo Basin.

There are eleven inherent soil constraints for food production in the Congo Basin:

1. *Low CEC:* low capacity to retain added nutrients.
2. *Aluminium toxicity:* strong acidity.
3. *High phosphorus fixation:* a high level of ferric oxides in the clay fraction.
4. *High decomposition rate of OM*: the nitrogen in soil OM remains the most important source of nitrogen for crop production in the Congo Basin. OM develops negative charges that contribute to the cation retention of the soil.
5. *pH value less than 5,5 (high acidity).*

6. *Hydromorphy:* poor soil drainage.
7. *Soil-water relationship*: Ferralsols and other soils dominated by LAC have a low available water content compared with soils characterized by HAC. This may represent serious limitations especially under seasonally dry climates.
8. *Low silt content* (texture).
9. *Porosity*: prolonged cultivation of annuals does not cause an important change of total pores but may be at the origin of a decrease of the macroporosity in the topsoil due to a decline in the OM content. This decrease in macroporosity may reduce root penetration.
10. *Shallowness*: rock or a rock-like horizon close to the soil surface.
11. *Erosion hazard:* a high risk of soil erosion, caused by steep slopes or moderate slopes in association with erosion-prone soils.

Limitation levels of different land characteristics for each land unit vary with respect to the requirements of the Land Utilization Types. A summary of limitations levels for common Land Utilization Type in the Congo Basin is given in table 5.

Table 5
Limitation levels of soil characteristics affecting common crops in the Congo Basin

	Depth of horizon			Moisture conditions			Plant nutrients			Soil acidity			OM		
	Maize	Rice	Cassava	Maize	Rice	Cassava	Maize	Rice	Cassava	Maize	Rice	Cassava	Maize	Rice	Cassava
Xanthic Ferralsol	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H
Haplic Acrisol	L	L	L	L	L	L	H	H	H	H	M	M	H	H	H
Haplic Arenosol	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H
Eutric Cambisol	L	L	L	L	L	L	H	H	H	H	M	M	H	H	H
Gleyic Acrisol	M	M	M	M	M	M	H	H	H	H	M	M	H	H	H

H = High; M = Medium; L= Low.

7. Agricultural Value and Land Use

The Congo Basin is characterized by diverse agricultural systems that are typically low input and based on subsistence farming. Agricultural intensification in the Congo Basin, through clearing and clean cultivation of soils for

annual cropping, almost causes a decline in SOM content. With the amount of SOM reduced there is a need to supplement the soil with additional nutrients in the form of fertilizers. It has been shown that intensive continuous cropping with annuals is possible with adequate use of fertilizers after annulation of the phosphorus fixation capacity and Al-saturation. A problem arises because many resource-poor farmers cannot obtain fertilizers and are forced, by their circumstances, to consider SOM as a source of nutrients to be exploited (CRASWELL *et al.* 2001). Another major practical problem in the humid tropics is to find liming materials of sufficient fineness and purity. The well-established practice of liming to neutrality is not effective in most of the HWS of the tropics.

8. Conclusion

As the population in the Congo Basin increases and the demand for food rises, there will be an increasing demand for suitable agricultural land to provide the agricultural products. Farmers will have to decide whether they are more concerned with short-term yields or long-term sustainability and soil management. Their decisions are very critical as recent research has shown that the conversion of tropical forests to sustainable agriculture may be detrimental to preventing global climate change.

In order to translate soil characteristics into agronomic constraints and land-use suitability we need detailed information from soil maps. There are some substantial data limitations to the sources used. The reliability of some of the maps and data is known to be relatively low.

Soil degradation, and in particular the decline of soil chemical fertility, is a major concern in relation to food production and agricultural sustainability in the Congo Basin. Soil nutrients and OM conservation are practices that require further attention if agriculture sustainability is expected to meet the increasing global demand for food.

REFERENCES

BAERT, G., VAN RANST, E., NGONGO, M. L., KASONGO, E. L., VERDOODT, A., MUJINYA, B. B. & MUKALAY, J. M. 2009. Guide des sols en RD Congo. Description et Données Physico-Chimiques de Profils Types. Tome II. Lubumbashi, Presse Salama, 321 pp.

BAERT, G., VAN RANST, E., NGONGO, M. L. & VERDOODT, A. 2013. Soil Survey in DR Congo – from 1935 until today. — *Meded. Zitt. K. Acad. Overzeese Wet.*, **59** (2): 345-362.

CLEAVER, K. M. & SCHREIBER, G. A. 1994. Reversing the Spiral: The population, agriculture and environment Nexus in Sub-Saharan Africa. — Washington DC, The World Bank, 293 pp.

CRASWELL, E. T. & LEFROY, R. D. B. 2001. The role and function of organic matter in tropical soils. — *Nutrient Cycling in Agroecosystems*, **61** (1): 7-18.

DRIESSEN, P., DECKERS, J., SPAARGAREN, O. & NACHTERGAELE, F. 2001. Lectures notes on the major soils of the world. World Soil Resources Reports 94. — Rome, Food and Agriculture Organization of the United Nations, 337 pp.

EL-SWAIFY, S. A. 1980. Physical and mechanical properties of Oxisols. — *In*: THENG, B. K. G. (Eds.), Soils with variable charge. — New Zealand Society of Soil Science, Lower Hutt, pp. 303-324.

FAO 2006. World Reference Base for Soil Resources. A framework for international classification, correlation and communication. World Soil Resources Reports 103. — Rome, Food and Agriculture Organization of the United Nations, 128 pp.

FAO-UNESCO-ISRIC 1988. Soil Map of the World, Revised Legend. — World Soil Resources Report no. 60, Rome, FAO, 119 pp.

JENKINSON, D. S. 1990. Turnover of organic carbon and nitrogen in soil. — London, Phil. Trans. R. Soc., Ser. B 329, pp. 361-368.

JONES, A., BREUNING-MADSEN, H., BROSSARD, M., DAMPHA, A., DECKERS, J., DEWITTE, O., GALLALI, T., HALLETT, S., JONES, R., KILASARA, M., LE ROUX, P., MICHELI, E., MONTANARELLA, L., SPAARGAREN, O., THIOMBIANO, L., VAN RANST, E., YEMEFACK, M. & ZOUGMORE, R. (Eds.) 2013. Soil Atlas of Africa. — Luxembourg, European Commission, Publications Office of the European Union, 176 pp.

KESSEBA, A. M. 1993. Strategies for developing a viable and sustainable agriculture sector in Sub-Saharan Africa: Some issues and options. — *In*: RAGLAND, J. & LAL, R. (Eds.), Technologies for Sustainable Agriculture in the Tropics. Madison, WI., Publ. Amer. Soc. Agron., ASA Special Publ. 56, pp. 211-244.

NACHTERGAELE, F. & VAN RANST, E. 2003. Qualitative and Quantitative Aspects of Soil Databases in Tropical Countries. — *In*: Evolution of Tropical Soil Science: Past and Future (Workshop, Brussels, 6 March 2002), Royal Academy of Overseas Sciences, pp. 107-126.

NGONGO, M. L., VAN RANST, E., BAERT, G., KASONGO, E. L., VERDOODT, A., MUJINYA, B. B. & MULALAY, J. 2009. Guide des sols en R.D. Congo. Tome I: Etude et Gestion. — Lubumbashi, Presse Salama, 260 pp.

SYS, C. 1960. Carte des sols du Congo Belge et du Ruanda-Urundi. Notice explicative de la carte des sols. — Bruxelles (Belgique), INEAC.

SYS, C. 1979. Regional Pedology. Tropical soils. Part II. International Training Centre for Post-graduate Soil Scientists. Lecture notes. — State University of Ghent.

VAN ENGELEN, V., VERDOODT, A., DIJKSHOORN, K. & VAN RANST, E. 2006. Soil and Terrain Database of Central Africa - DR Congo, Burundi and Rwanda. — SOTERCAF, Version 1.0. ISRIC-UGent-FAO.

VAN RANST, E. 1994. Rational soil management in the humid tropics. — In: *Meded. Zitt. K. Acad. Overzeese Wet.*, **40** (2): 209-233.

VAN RANST, E. 2004. Properties and management of soils of the tropics. — Intern. Course Program "Physical Land Resources", Ghent University (Belgium), 286 pp.

VAN WAMBEKE, A. 1989. Tropical Soils and Soil Classification Updates. — *Advances in Soil Science*, **10**: 171-193. New York Inc., Springer Verlag.

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Remote Sensing: a Key Tool for Monitoring Food Resources in a Changing World

by

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KEYWORDS. — Remote Sensing; Food Production; Crop and Livestock Production.

SUMMARY. — Remote Sensing (RS) has been adapted as standard technology for monitoring the earth's surface. Especially in data-poor countries or in areas under conflict, remote sensing imagery is often the only independent data source available. Both the USA and Europe offer a range of low-resolution satellite products (spatial resolution of 1 km by 1 km) available to the general public that can be used as indirect or direct proxy for food production. Based on these images, food-monitoring tools mostly focusing on crop production are readily distributed. In addition to the models available for crop food production, there is a need for monitoring livestock production as in many African countries livestock is an important resource that contributes to food security, improves the quality of life of farmer communities and strengthens the development of the economy. Crop and animal health both impact directly on the obtained production. Additionally, zoonoses, *i.e.*, diseases that can be transmitted from animals to humans, may also have an important impact on public health, especially when seen from a One-Health perspective.

This paper discusses the advantages and disadvantages of currently available spatial decision-making tools using RS as input both for crop and livestock production in Africa. The potential increase of existing diseases and the risk of emerging diseases under global change are illustrated with a case study in Zambia.

Introduction

Over the last thirty years, remote sensing data have become a prime data source to be used as a tool for monitoring food resources. Remote sensing data are independent, allow measurements in areas difficult to reach due to

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remoteness or societal upheaval, provide continuous measurement of the earth surface in multiple spectral channels and have a long-term sustainability.

In general, RS sensors can be grouped into two categories: passive and active sensors. Passive sensors are the best known group of sensors. The platform will sense the reflectance of the sunlight on the earth's surface in multiple channels and these reflectance values can be post-processed to create indices for vegetation status, and hence crop status (LILLESAND *et al.* 2004), using vegetation indices (see JIANG *et al.* 2008 for review). Other indices include for example temperature indices (PRICE 1984, WAN 2008).

Each sensor is carried on board a satellite platform which is either geostationary or polar-orbiting. The geostationary satellites, as the name states, take images constantly over the same area. All geostationary satellites combined sense the entire globe (with exception of the very high latitudes). MSG satellites (EUMETSAT) have their focus on Africa (www.eumetsat.int). Polar-orbiting satellites are moving around the globe and have a revisit time of the same area ranging between one day (Aqua http://aqua.nasa.gov; Terra http://terra.nasa.gov; SPOT VEGETATION http://www.vgt.vito.be) and two-three weeks (SPOT www.astrium-geo.com/en/143-spot-satellite-imagery; Landsat http://landsat.gsfc.nasa.gov) or even *ad hoc* (Quickbird http://www.satimagingcorp.com/satellite-sensors/quickbird.html; Ikonos http://www.satimagingcorp.com/satellite-sensors/ikonos.html; Worldview 2 https://www.digitalglobe.com/about-us/content-collection). Clouds limit the use of passive RS data as the satellite platform cannot measure areas covered by clouds. Especially in the tropics this can hamper routine sensing a study site. Compositing techniques can overcome this through the identification of pixels contaminated by clouds (HOLBEN 1986; JONSSON & EKLUNDH 2002, 2004; MA & VEROURSTRAETE 2006; JULIEN & SOBRINO 2010). The data are usually composited between 7 and 16 days.

Active sensors send out actively a signal that is consequently recaptured by the same sensor. This type of radar sensing is commonly used for hydrological purposes, mainly to assess soil moisture. Sometimes active sensors are used in areas under heavy cloud contamination, *e.g.*, in tropical areas during the wet season, as the active signal can penetrate the clouds and thus can 'see' through the clouds (*e.g.*, BWANGOY *et al.* 2010).

Remotely sensed imagery is characterized by four types of resolution: spatial, temporal, spectral and radiometric resolution. The spatial or ground resolution is probably the best known type of resolution and refers to the size of the smallest object that can be resolved on the ground. It is determined by

the Instantaneous Field of View (IFOV) of the remote sensing system, which is the cone angle within which incident energy is focused on a sensor's detector, and the distance between the satellite platform and the target being imaged. The smaller the IFOV, the higher the spatial resolution and the finer the spatial detail that can be distinguished. The spatial resolution is usually expressed in metre, ranging from coarse (> 100 m), over medium (30-100 m) and high (4-30 m) to very high (< 4 m). The temporal resolution or revisit time specifies the amount of time needed to revisit and acquire data for a specific location. This depends on the orbital characteristics of the platform and characteristics such as swathe-width. The geostationary satellites sense the same area continuously and provide a measurement every 15 min. Polar orbiting satellites have a revisit time from 1 day up to 2-3 weeks. By using multiple satellites with the same sensors, the revisit time is sometimes reduced to half a day (*e.g.*, Terra and Aqua satellites carrying the MODIS sensor). The spectral resolution is determined by the amount of bands or channels used to measure the reflectance from the earth's surface, going from a simple RGB sensor (3 channels) over multispectral (5-30 channels) to hyperspectral cameras (> 100 very narrow channels). Finally, the number of bits used to store the reflectance values on board the satellite determines the radiometric resolution, *i.e.*, the sensor's ability to discriminate very slight differences in reflected or emitted energy.

Remote Sensing as Tool for Food Monitoring

Remote sensing data products have found numerous applications in the agricultural sector (crops, livestock and fisheries) and have become an increasingly important component in improving food and nutrition security and developing famine early-warning systems (BROWN 2008, ATZBERGER 2013, MULLA 2013). The choice of which spectral bands to use and the temporal and spatial resolution required to meet the study objectives will provide the basis for selecting the appropriate satellite sensor. Vegetation indices, such as the Enhanced Vegetation Index (EVI) or Normalized Difference Vegetation Index (NDVI), derived from multi-temporal satellite data with a medium to coarse spatial resolution have been successfully used for crop monitoring over extensive areas (*e.g.*, regional and national scales). These vegetation indices combine the absorptive and reflective characteristics of vegetation in the visible red and near-infrared portions of the electromagnetic spectrum to obtain a measure of canopy greenness, which is used to quantify

vegetation amounts and vigour (BANNARI *et al.* 1995). Several studies have demonstrated the utility of 1 km NDVI time-series derived from the Advanced Very High Resolution Radiometer (AVHRR) instruments on board the National Oceanic and Atmospheric Administration (NOAA) satellites for agricultural monitoring at large spatial scales, *e.g.*, for studying rangeland condition (HIELKEMA *et al.* 1986, MINOR *et al.* 1999, WEISS *et al.* 2001, GEERKEN & ILAIWI 2004), crop phenology (WENBIN *et al.* 2009, SEGHAL *et al.* 2011, YOU *et al.* 2013), and crop area estimation and yield forecasting (HUANG *et al.* 2013). Major aid organizations, such as the Food and Agricultural Organization (FAO), have set up operational early-warning systems based on the integrative use of medium to coarse spatial resolution sensors and crop growth modelling to mitigate food insecurity (*e.g.*, HIELKEMA & SNIJDERS 1994). If the study objective is to monitor crop status at farm level, imagery with a high spatial resolution and moderate temporal resolution will be needed. For instance, the improved resolution characteristics of the Moderate Resolution Imaging Spectroradiometer (MODIS, 36 spectral bands and daily global imagery at spatial resolutions of 250-500 m) provide a substantially improved basis for retrieval of crop biophysical parameters at both field and regional scales that could be integrated in crop-yield simulation models (DORAISWARMY *et al.* 2005, ARVOR *et al.* 2011). Other examples include the use of Landsat TM or SPOT images (RUDORFF & BATISTA 1991, CONRAD *et al.* 2010, YANG *et al.* 2011). Careful balancing is required as the combination of high spatial and high temporal resolution is still limited. SPOT will be able to offer now 10-m images every day with the new programme, but for current operational monitoring this is yet to become integrated.

While research has primarily focused on the use of RS data for crop monitoring, livestock monitoring has been left out, even though the World Bank assessed the potential contribution of the livestock sector to agricultural/economic growth and poverty alleviation very high. Meat and dairy are considered high-value livestock products, and a significant unidirectional relationship between livestock development and GDP has been established in thirty-three developing countries, including the Democratic Republic of Congo (PICA *et al.* 2008). ROBINSON *et al.* (2007) provided maps of livestock distribution and livestock production globally. They used remotely sensed predictor variables to create these livestock distribution maps. Especially in extensive farming systems, the distribution of livestock is linked to the prevailing environmental conditions. These conditions can be measured from the satellite and therefore be used as main data source. These livestock distribution maps are currently being updated (ROBINSON *et al.*, under revision).

In Asia, there is considerable focus on the distribution of ducks and geese, not only important for food security but also very relevant in the framework of highly pathogenic avian influenza (PROSSER *et al.* 2011, VAN BOEKEL *et al.* 2011). In Africa, BRYSSINCKX *et al.* (2012) focused on the improved estimation of livestock in Uganda from survey data by adapting the sampling strategy and including RS data for the stratification.

Livestock distribution in Africa is closely related to vector-borne diseases. Tsetse-fly-transmitted trypanosomiasis is a major constraint to rural development in large parts of Africa (SWALLOW 1998). The tsetse flies occur in about 10 million km^2 of sub-Saharan Africa and the trypanosomes they transmit can cause severe illness in livestock and people. Animal African Trypanosomiasis (AAT) in the Democratic Republic of Congo is transmitted by *Glossina tabaniformis* (LEAK *et al.* 1991) and the prevalence is estimated at 4.5-9.5 %. DE DEKEN *et al.* (2005) demonstrated that Human African Trypanosomiases (HAT) and AAT in Kinshasa are transmitted by *Glossina fuscipes quanzensis*. SIMO *et al.* (2006) indicated from bloodmeal analysis that transmission not only involves flies and humans but also pigs, hereby illustrating the complexity of transmission. Indeed, SUMBU *et al.* (2009) established that pigs act as reservoir for HAT in Kinshasa. Because of the complexity and the limited availability of studies in Congo, the case study shown here is focusing on the Eastern Province in Zambia, where the seasonal distribution of the tsetse fly is correlated with the distribution of its main host, cattle (VAN DEN BOSSCHE & STAAK 1997). The case study demonstrates the use of remote sensing data to measure the impact of gradual forest clearance on the inherent apparent density of tsetse flies.

Case Study

In large parts of tsetse-infested sub-Saharan Africa the progressive clearing of the natural vegetation for cultivation, the introduction of domestic animals and the almost complete disappearance of big-game animals have had important repercussions for the distribution and density of tsetse flies. It can be anticipated that in the years to come and with continued population growth and environmental change, a similar decline in the distribution and density of the tsetse population and the disease prevalence will be observed in Zambia as well. This process of gradual reduction may in certain areas ultimately lead to autonomous, anthropogenic clearing of tsetse and thus the disappearance of the disease (BOURN *et al.* 2000, REID *et al.* 2000).

Understanding this process may contribute to the development of focused trypanosomiasis control strategies that exploit this autonomous tsetse clearing.

To this end, DUCHEYNE *et al.* (2009) used remote sensing to analyse the impact of land-cover change on the abundance of tsetse flies. Whilst land-cover change is often mapped and included in data analysis, incorporating the fragmentation level of different land-cover types is less common. The arrival of software tools such as Fragstats does allow quantifying the fragmentation and, consequently, establishing the relationship between fragmentation and species distribution and abundance.

Inherent apparent density (IAD) of tsetse flies was calculated using survey results following the fly-round method along transects as described by POTTS (1930) and FORD *et al.* (1959). The fly-rounds were 6 km long and had about 30 sectors of roughly 200 m each. At the end of each sector was a stop. All transects were georeferenced to facilitate reallocation. The fly-rounds were surveyed twice in 2006: once in the rainy season and once in the hot dry season.

Two Landsat images, with a spatial resolution of 30 m, were preprocessed separately prior to mosaicking to reduce any effects of illumination differences and atmospheric absorption. The digital numbers (pixel values) were converted into near-surface reflectance taking into account atmospheric correction using a dark pixel subtraction method (CHAVEZ 1988). Subsequently, they were co-registered to remove any geometric distortions using a second-order polynomial followed by a nearest neighbour resampling method. Finally, the imagery was mosaicked using a grey-level matching method (RICHARDS & JIA 1999). The images were then classified into four land-cover types: *i.e.*, munga, miombo, agriculture and villages. Two auxiliary categories were also included, *i.e.*, cloud and shadow.

The fragmentation was calculated using the classified remote land-cover maps. For each land-cover type a moving hexagonal window was applied to determine the total class area, number of patches, mean patch-size and patch size standard deviation. Based on these indices, the hexagons with similar fragmentation characteristics were grouped in classes using an unsupervised clustering method named Partitioning Around Medoids (PAM).

The outcome of this study shows that in the study area the destruction and fragmentation of the natural habitat of tsetse flies has significant repercussions for the density of those flies. Extensive clearing, mainly for cotton production in the southern part of the study area, has resulted in the disappearance of large parts of the tsetse habitat and in a significant reduction in

the apparent density of tsetse compared to areas closer to the Luangwa escarpment, where human density is much lower and the natural vegetation largely undisturbed. The results from this study suggest that the effect of habitat fragmentation on the apparent density of male and female tsetse flies is a gradual process with the inherent apparent density of tsetse decreasing with increasing levels of fragmentation. This relationship is not linear; the decrease in inherent apparent density only starts when a threshold in fragmentation is reached.

Conclusion

Remote sensing data offer the potential to closely monitor agricultural resources as early-warning system for potential crop failure and to map livestock distribution. Given the anticipated global changes, remote sensing data are a valuable tool to estimate potential reduction in crop productivity or degradation in livestock zones.

REFERENCES

ARVOR, D., JONATHAN, M., MEIRELLES, M. S. P., DUBREUIL, V. & DURIEUX, L. 2011. Classification of MODIS EVI time series for crop mapping in the state of Mato Grosso, Brazil. — *International Journal of Remote Sensing*, **32** (22): 7847-7871. DOI:10.1080/01431161.2010.531783

ATZBERGER, C. 2013. Advances in remote sensing of agriculture: Context description, existing operational monitoring systems and major information needs. — *Remote Sensing*, **5** (2): 949-981. DOI:10.3390/rs5020949

BANNARI, A., MORIN, D., BONN, F. & HUETE, A. R. 1995. A review of vegetation indices. — *Remote Sensing Reviews*, **13** (1-2): 95-120. DOI:10.1080/02757259509532298

BOURN, D., REID, R. S., ROGERS, D., SNOW, W. F. & WINT, W. 2000. Environmental Change and the Autonomous Control of Tsetse and Trypanosomosis in Sub-Saharan Africa. — AHP/ERGO, 248 pp.

BROWN, M. E. 2008. Famine Early Warning Systems and Remote Sensing Data. — Berlin-Heidelberg, Springer.

BRYSSINCKX, W., DUCHEYNE, E., MUHWEZI, B., GODFREY, S., MINTIENS, K., LEIRS, H. & HENDRICKX, G. 2012. Improving the accuracy of livestock distribution estimates through spatial interpolation. — *Geospatial Health*, **7** (1): 101-109.

BWANGOY, J.-R., HANSEN, M. C., ROY, P. R., DE GRANDI, G. & JUSTICE, C. O. 2010. Wetland mapping in the Congo Basin using optical and radar remotely sensed data and derived topographical indices. — *Remote Sensing of Environment*, **114** (1): 73-86. DOI:http://dx.doi.org/10.1016/j.rse.2009.08.004

CHAVEZ, Jr., P. S. 1988. An improved dark-object subtraction technique for atmospheric scattering correction of multispectral data. — *Remote Sensing of Environment*, **24** (3): 459-479. DOI:http://dx.doi.org/10.1016/0034-4257(88)90019-3

CONRAD, C., FRITSCH, S., ZEIDLER, J., RUCKER, G. & DECH, S. 2010. Per-field irrigated crop classification in arid Central Asia using SPOT and ASTER data. — *Remote Sensing*, **2** (4): 1035-1056. DOI:10.3390/rs2041035

DE DEKEN, R., SUMBU, J., MPIANA, S., MANSINSA, P., WAT'SENGA, F., LUTUMBA, P., BOELAERT, M. & VAN DEN BOSSCHE, P. 2005. Trypanosomiasis in Kinshasa: distribution of the vector *Glossina fuscipes quanzensis*, and risk of transmission in the peri-urban area. — *Medical Veterinary Entomology*, **19** (4): 353-359. DOI:10.1111/j.1365-2915.2005.00580.x

DORAISWAMY, P. C., SINCLAIR, T. R., HOLLINGER, S., AKHMEDOV, B., STERN, A. & PRUEGER, J. 2005. Application of MODIS derived parameters for regional crop yield assessment. — *Remote sensing of environment*, **97** (2): 192-202. DOI:http://dx.doi.org/10.1016/j.rse.2005.03.015

FORD, J., GLASGOW, J. P., JOHNS, D. L. & WELCH, J. R. 1959. Transect fly-rounds in the field studies of *Glossina*. — *Bulletin of Entomological Research*, **50** (02): 275-285. DOI:http://dx.doi.org/10.1017/S0007485300054584

GEERKEN, R. & ILAIWI, M. 2004. Assessment of rangeland degradation and development of a strategy for rehabilitation. — *Remote Sensing of Environment*, **90** (4): 490-504. DOI:http://dx.doi.org/10.1016/j.rse.2004.01.015

HIELKEMA, J. U. & SNIJDERS, F. L. 1994. Operational use of environmental satellite remote sensing and satellite communications technology for global food security and locust control by FAO: The ARTEMIS and DIANA systems. — *Acta Astronautica*, **32** (9): 603-616. DOI:http://dx.doi.org/10.1016/0094-5765(94)90071-X

HIELKEMA, J. U., PRINCE, S. D. & ASTLE, W. L. 1986. Rainfall and vegetation monitoring in the savanna zone of the Democratic Republic of Sudan using the NOAA Advanced Very High Resolution Radiometer. — *International Journal of Remote Sensing*, **7** (11): 1499-1513. DOI:10.1080/01431168608948950

HOLBEN, B. N. 1986. Characteristics of maximum-value composite image from temporal AVHRR data. — *International Journal of Remote Sensing*, **7** (11): 1417-1434. DOI:10.1080/01431168608948945

HUANG, J., WANG, X., LI, X., TIAN, H. & PAN, Z. 2013. Remotely sensed rice yield prediction using multi-temporal NDVI data derived from NOAA's-AVHRR. — PloS one, **8** (8), e70816. DOI:10.1371/journal.pone.0070816

JIANG, Z., HUETE, A. R., DIDAN, K. & MIURA, T. 2008. Development of a two-band enhanced vegetation index without a blue band. — *Remote sensing of Environment*, **112** (10): 3833-3845. DOI:http://dx.doi.org/10.1016/j.rse.2008.06.006

JONSSON, P. & EKLUNDH, L. 2002. Seasonality extraction by function fitting to time series of satellite sensor data. — *IEEE Transactions on Geoscience and Remote Sensing*, **40** (8): 1824-1832. DOI:10.1109/TGRS.2002.802519

JONSSON, P. & EKLUNDH, L. 2004. TIMESAT – A program for analyzing time-series of satellite sensor data. — *Computers and Geoscience*, **30** (8): 833-845. DOI:http://dx.doi.org/10.1016/j.cageo.2004.05.006

JULIEN, Y. & SOBRINO, J. A. 2010. Comparison of cloud-reconstruction methods for time series of composite NDVI data. — *Remote Sensing of Environment*, **114** (3): 618-625. DOI:http://dx.doi.org/10.1016/j.rse.2009.11.001

LEAK, S. G. A., COLARDELLE, C., D'IETEREN, G., DUMONT, P., FERON, A., JEANNIN, P., MINENGU, M., NGAMUNA, S., ORDNER, G., SAUVEROCHE, B., TRAIL, J. C. M. & YANGARI, G. 1991. — *Glossina fusca* group tsetse as vectors of cattle trypanosomiasis in Gabo and Zaire. — *Medical and Veterinary Entomology*, **5** (1): 111-120. DOI:10.1111/j.1365-2915.1991.tb00528.x

LILLESAND, T. M., KIEFER, R. W. & CHIPMAN, J. W. 2004. Remote Sensing and Image Interpretation. — Wiley New York, 721 pp.

MA, M. & VEROUSTRAETE, F. 2006. Reconstructing pathfinder AVHRR land NDVI timeseries data for the Northwest of China. — *Advances in Space Research*, **37** (4): 835-840. DOI:http://dx.doi.org/10.1016/j.asr.2005.08.037

MINOR, T. B., LANCASTER, J., WADE, T. G., WICKHAM, J. D., WHITFORD, W. & JONES, K. B. 1999. Evaluating change in rangeland condition using multitemporal AVHRR data and geographic information system analysis. — *Environmental Monitoring and Assessment*, **59** (2): 211-223. DOI:10.1023/A:1006126622200

MULLA, D. J. 2013. Twenty-five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps. — *Biosystems Engineering*, **114** (4): 358-371. DOI:http://dx.doi.org/10.1016/j.biosystemseng.2012.08.009

PICA, G., PICA-CIAMARRA, U. & OTTE, J. 2008. The Livestock Sector in the World Development Report 2008: Re-assessing the Policy Priorities. — PPLPI Research Report, 10 pp.

POTTS, W. H. 1930. A contribution to the study of numbers of tsetse-fly (*Glossina morsitans* Westw.) by quantitative methods. — *South African Journal of Science*, **27**: 491-497.

PRICE, J. 1984. Land surface temperature measurements from the split window channels of the NOAA 7 Advanced Very High Resolution Radiometer. — *Journal of Geophysical Research: Atmospheres*, **89** (D5): 7231-7237. DOI:10.1029/JD089iD05p07231

PROSSER, D. J., WU, J., ELLIS, E. C., GALE, F., VAN BOECKEL, T. P., WINT, W., ROBINSON, T., XIAO, X. & GILBERT, M. 2011. Modelling the distribution of chickens, ducks, and geese in China. — *Agriculture, Ecosystems & Environment*, **141** (3): 381-389. DOI:http://dx.doi.org/10.1016/j.agee.2011.04.002

REID, R. S., KRUSKA, R. L., DEICHMANN, U., THORNTON, P. K. & LEAK, S. G. A. 2000. Human population growth and extinction of the tsetse fly. — *Agriculture Ecosystems and Environment*, **77** (3): 227-236. DOI:http://dx.doi.org/10.1016/S0167-8809(99)00103-6

RICHARDS, J. A. & JIA, Y. 1999. Remote Sensing Digital Image Analysis: An Introduction, 3rd ed. — Berlin, Springer, 363 pp.

ROBINSON, T., FRANCHESCHINI, G. & WINT, W. 2007. The food and agriculture organizations's gridded livestock of the world. — *Veterinaria Italiana*, **43** (3): 745-751.

ROBINSON, T., WINT, W., CONCHEDDA, T. G., VAN BOECKEL, T. P., ERCOLI, V., PALAMARA, E., CINARDI, G., D'AIETTI, L. & GILBERT, M. In revision. Mapping the global distribution of livestock. — *Plos ONE.*

RUDORFF, B. F. T. & BATISTA, G. T. 1991. Wheat yield estimation at the farm level using TM Landsat and agrometeorological data. — *International Journal of Remote Sensing*, **12** (12): 2477-2484. DOI:10.1080/01431169108955281

SEHGAL, V. K., JAIN, S., AGGARWAL, P. K. & JHA, S. 2011. Deriving crop phenology metrics and their trends using times series NOAA-AVHRR NDVI Data. —

Journal of the Indian Society of Remote Sensing, **39** (3): 373-381. DOI:10.1007/s12524-011-0125-z

SIMO, G., MANSINSA DIABAKANA, P., KANDE BETU KU MESU, V., MANZAMBI, E. Z., OLLIVIER, G., ASONGANYI, T., CUNY, G. & GREBAUT, P. 2006. Human African Trypaonosomiasis Transmission, Kinshasa, Democratic Republic of Congo. — *Emerging Infectious Diseases*, **12** (12): 1968-1970. DOI:http://dx.doi.org/10.3201%2Feid1212.060516

SUMBU, J., DE DEKEN, R., DECKERS, N., MPIANA, S, KABAMBI, P. TSHILENGE, G. & BOELAERT, M. 2009. Variation spatiale du risque pour les porcs de contracter la trypanosomose dans ls zone périurbaine de Kinshasa. — *Parasite*, **16** (2): 153-159. DOI:10.1051/parasite/2009162153

SWALLOW, B. M. 1998. Impacts of African Animal Trypanosomosis on Migration, Livestock and Crop Production. — Nairobi, ILRI, pp. 1-19.

VAN BOECKEL, T., PROSSER, D., FRANCESCHINI, G., BIRADAR, C., WINT, W., ROBINSON, T. & GILBERT, M. 2011. Modelling the distribution of domestic duck in Monsoon Asia. — *Agriculture, Ecosystems and Environment*, **141** (3-4): 373-380. DOI: 10.1016/j.agee.2011.04.013

VAN DEN BOSSCHE, P. & STAAK, C. 1997. The importance of cattle as a food source for *Glossina morsitans morsitans* Westwood (Diptera: Glossinidae) in Katete District, Eastern Province, Zambia. — *Acta Tropica,* **65** (2): 105-109. DOI:http://dx.doi.org/10.1016/S0001-706X(97)00658-X

WAN, Z. 2008. New refinements and validation of the MODIS Land-Surface Temperature/Emissivity products. — *Remote Sensing of Environment*, **112** (1): 59-74. DOI:http://dx.doi.org/10.1016/j.rse.2006.06.026

WEISS, E., MARSH, S. E. & PFIRMAN, E. S. 2001. Application of NOAA-AVHRR NDVI time-series data to assess changes in Saudi Arabia's rangelands. — *International Journal of Remote Sensing*, **22** (6): 1005-1027. DOI:10.1080/014311601300074540

WENBIN, W., PENG, Y., HUAJUN, T., SHIBASAKI, R., QINGBO, Z. & LI, Z. 2009. Monitoring spatial patterns of cropland phenology in North China based on NOAA NDVI data. — *Scientia Agricultura Sinica*, **42** (2): 552-560.

YANG, C., EVERITT, J. H. & MURDEN, D. 2011. Evaluating high resolution SPOT 5 satellite imagery for crop identification. — *Computers and Electronics in Agriculture*, **75** (2): 347-354. DOI:http://dx.doi.org/10.1016/j.compag.2010.12.012

YOU, X., MENG, J., ZHANG, M. & DONG, T. 2013. Remote sensing based detection of crop phenology for agricultural zones in China using a new threshold method. — *Remote Sensing*, **5** (7): 3190-3211. DOI:10.3390/rs5073190

POSTERS

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Legacy Soil Survey Data of DR Congo

by

Geert BAERT[*,**], Ann VERDOODT[***],
Michel NGONGO[****] & Eric VAN RANST[*]

KEYWORDS. — Legacy Soil Data; Soil Survey; Soil Classification; INEAC; Soil Profiles.

SUMMARY. — To support the agricultural development during and after colonization of DR Congo, many soil surveys have been undertaken. This poster gives a review of the history of the soil survey in DR Congo from 1935 until present, and of the different institutions involved in soil survey. The soil prospection in Congo can be separated in different distinct periods of activities and methodologies, related to some major important national or international events. The first soil surveys conducted by J. Baeyens in 1935 (KU Leuven) were the start of a vast soil survey programme carried out by INEAC (National Institute for Agricultural Research in Belgian Congo). From 1945 onwards, INEAC was fully developed, with the principal research station in Yangambi and thirty-one substations (research stations, experimental stations and plantations, ...) all over Congo, located in different agroclimatic zones. During the course of the soil prospection, the INEAC soil survey team developed their own soil classification system inspired by the Soil Survey Manual. When this programme was stopped at independence in 1960, around 15 % of the territory was mapped, spread over the different agro-ecological zones of the country. After 1960, most of the soil surveys in DR Congo were conducted by the Laboratory for Soil Science of the Ghent University. It entailed semi-detailed mapping for industrial agriculture and systematic reconnaissance surveys for general agricultural development (Lower Congo and Plain of the Ruzizi). The delimitation and characterization of the soil units distinguished on the digitized soil maps are based on thousands of soil profiles and a very large number of soil analyses conducted in specialized soil laboratories.

This poster clearly illustrates the availability of a large amount of soil data, although scattered, of DR Congo, both soil maps and analytical data, which were collected over a long period. The numerous soil surveys in different agro-ecological zones of the country played an important role in the development of tropical soil science, soil classification, and in determining the land-use potential for agricultural development in tropical regions.

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Design of a Soil Information System for DR Congo

by

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KEYWORDS. — Legacy Soil Data; Digitalization; Soil Information System; Soil and Terrain Database.

SUMMARY. — Given the economic importance of agriculture in the Congo Basin, there has always been a great need for soil information. This poster illustrates the design of a soil information system of DR Congo using legacy soil data collected from 1935 until present. A multitude of soil survey data were collected in the DR Congo from 1935 till the 1990s. However, since 1960, during the major events and subsequent periods of instability that took place in DR Congo, a major part of the legacy soil data was lost. Other data were not easily accessible as they had not been published.

To prevent further loss of the existing soil data and increase accessibility to Congolese and other scientists, soil maps, exploratory texts and technical reports were stored in a digital soil database by the Laboratory of Soil Science of the Ghent University in collaboration with the Laboratories of Soil Science of the Universities of Lubumbashi and Kinshasa (VLIR-funding). Availability of existing natural resources data of DR Congo enabled to develop a SOTER (SOil and TERrain) database for Central Africa in 2006-2007 in the frame of an ISRIC-UGent-FAO project. The methodology focused on the identification of areas of land with a distinctive pattern of landform, lithology, surface form, slope, parent material and soil. A physiographic map was derived after analysis of SRTM satellite data of the region. The geological map was translated into a lithological map. These thematic maps were combined to give the SOTER unit maps at scale 1:2M for the Democratic Republic of the Congo. Additional information characterizing the non-mappable terrain and soil components was selected, harmonized and inserted in a relational database of soil profile data.

The soil information system provides inputs in a large number of applications in DR Congo, such as land evaluation for food and industrial crops in different agro-ecological zones of DR Congo, investigation of soil hydraulic properties and modelling of carbon sequestration.

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Pedotransfer Functions: an Answer to the Lack of Hydrophysical Soil Properties for Sustainable Land Management in the South-Western Part of the Congo Basin

by

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KEYWORDS. — Pedotransfer Functions; K-nearest Neighbour; Soil Water Retention; Soils of the Humid Tropics; Lower Congo.

SUMMARY. — The south-western part of the Congo Basin (*i.e.*, Lower Congo) has been an active research area in the field of soil sciences since the 1940s. This has resulted in a comprehensive soil database, completed with climatological and agricultural data, for this region. However, information on hydraulic and physical properties, such as the soil water retention curve (SWRC) and bulk density (BD) of soils, is still missing. Reliable data on the SWRC are necessary for simulating the soil water balance and estimating crop yields under various management scenarios that are subjected to different rainfall regimes. The crop cycle of common crops in the Lower Congo can be fitted into the growing period taking into account climate-, soil- and crop-specific sowing dates and as such avoiding water stress conditions. Data on BD are needed for estimation of carbon stocks and nutrient status of soils. Measuring these hydrophysical properties is labour-intensive, time-consuming, expensive and causes additional difficulties in developing countries, like the DR

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Congo, ranging from staff training to the acquisition of the necessary equipment. Hydropedology, a recent discipline which bridges hydrology and pedology, has tried to circumvent this problem by the application of pedotransfer functions (PTFs). These are empirical relationships relating the soil hydraulic parameters to more easily measurable soil data such as soil texture, BD, organic matter content and/or other data routinely measured in soil surveys. Yet, most published PTFs have been developed for soils in the temperate areas and less effort has been dedicated to develop PTFs valid for soils of the humid tropics. The most widely published PTFs have been evaluated based on water retention measurements of several representative soils of the Lower Congo. Results have shown that there is not one single set of PTFs valid for application to the soils of this region. This preliminary study has recommended developing PTFs for estimating hydrophysical properties, such as the SWRC and BD designed for the Lower Congo region. This will allow full exploitation of the available natural resources data. We have tested various state-of-the-art approaches (*e.g.*, multiple linear regressions, k-nearest neighbour and the pore-solid fractal theory) for developing such PTFs. These functions have then been used to construct a preliminary map of hydraulic information for soils of the Lower Congo. This map, combined with the Soil and Terrain (SOTER) database for the DR Congo, will help to define guidelines for the optimization of agricultural production and environmental protection at different spatial scales.

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Food Security in the Democratic Republic of Congo

by

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KEYWORDS. — DR Congo; Food Security Status Data; Food Security Trends; Food Security Challenges.

SUMMARY. — The Democratic Republic of Congo (DR Congo) is still recovering from years of war and political upheaval, and continues to face significant humanitarian challenges. About 70 % of the population lacks access to adequate food, while one out of four children is malnourished (WFP 2012). Based on the recent Integrated Food Security Phase Classification (IPC) (December 2012), about 6.4 million people are in acute food security and livelihood crisis, requiring food and agricultural assistance. This figure represents an increase from 5.4 million in June 2012 to 6.3 million in October 2012. The level of food insecurity is worse in rural areas compared to urban areas (MICS [1]**** 2010). Vigorous reforms in the agricultural and economic sectors are required as well as consideration of nutrition to allow the reduction of poverty.

1. Introduction

The Democratic Republic of Congo (DR Congo) has adopted (MICS 2010) the definition of "food security" as defined by the World Food Summit held in Rome in 1996 [2].

According to the MICS (2010), the following three aspects of food security are taken under consideration by the DR Congo: availability (a sufficient supply of food, mainly from local production), accessibility (adequate access

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**** The numbers in brackets [ ] refer to the notes, pp. 88-89.

to food or means created by guaranteed means or incomes) and utilization (utilization of food ensuring the variety of diet, hygiene and health). Giving this definition of the MICS, nothing has been specified on the stability of food availability, which is normally considered to be one of the dimensions of the food security analysis.

The MICS themselves addressed the retained dimensions of food security by channelling on three tracks: (1) the frequency of food consumption, (2) the level of food consumption, and (3) the sources of food consumed and the stable supply of it for the Congolese households.

In the DR Congo, there is no explicit policy on food security. Nevertheless, within the Ministry of Agriculture, there is, since 2010, a "National Programme for Food Security"; this programme is expected to develop a national policy of the country for food security, but for lack of financial support, this programme is not yet operational.

In general, one can say that the food security data of the DR Congo are scarcely updated. Some data are only available at national level and not at household level; other data only concern subgroups of the population that are not representative for the national level. Finally, not all data have been officially published.

2. Food Security Situation in the Democratic Republic of Congo

The DR Congo is still recovering from years of war and political upheaval, and continues to face significant humanitarian challenges. About 70 % of the population lacks access to adequate food, while one out of four children is malnourished (WFP 2012). Based on the recent Integrated Food Security Phase Classification (IPC) (December 2012), about 6.4 million people are in acute food security and livelihood crisis, requiring food and agricultural assistance. This figure represents an increase from 5.4 million in June 2012 to 6.3 million in October 2012 compared to the 2011 estimation of 4.5 million people (IFPRI 2012).

The conflict in eastern DR Congo and Katanga continues to displace thousands of people. The June World Food Programme (WFP) (2013) assessment in conflict-affected North Kivu indicates that 61 % of the households is food insecure. In Katanga, the Global Acute Malnutrition (GAM) [3] rate is 13.8 % in Kabalo territory, according to the July 2013 MSF [4] nutrition survey. Meanwhile, maize and cassava flour prices remained above the three-

year average in markets monitored by the WFP and FAO. The price of vegetable oil increased in the DR Congo by 13 % [5].

In 2010, the WFP estimated at 12 % the proportion of households with poor food consumption, at 21 % the proportion of those with borderline food consumption and at 67 % the proportion of those with acceptable food consumption. At that time, the Congolese Government recognized that the majority of the Congolese households are food insecure.

In 2009, the global hunger index (GHI) [6] for the RD Congo was with 39.1 % the highest of all countries in the world. Already in 2002, the proportion of people suffering from food insecurity was estimated at 73 % (TOLLENS 2003, p. 25). With this proportion, the DR Congo was counted at that time among the twenty-three most affected countries by the problems of exceptional food emergencies: the country was ranked twenty-first lowest out of twenty-three in terms of kcal (energy) consumption.

At national level the food production is steadily declining: 90 % of the arable land is not cultivated, largely due to insecurity preventing access to fields and markets; 544 kcal drop in food supply *per capita* per day comparing 1992 with 2007, and the average daily protein supply in the DR Congo is 39.5 g (10 % of total available energy).

3. National Level Food Security Status of the DR Congo compared to other Countries in Southern Africa

The Global Food Security Index (GFSI) of the Economist Intelligence Unit (EIU 2013) considered the core issues of affordability, availability and quality across a set of 107 countries. The GFSI is a dynamic quantitative and qualitative scoring model, constructed from 27 unique indicators, that measures the drivers of food security across both developing and developed countries. The DR Congo ranks 107 out of 107 countries with a score [7] of 20.8/100 belonging to the group of low-income countries. Other neighbouring countries in that same group are doing it somewhat better (Burundi ranks 103 with score 26.3; Zambia ranks 100 with score 28.1; Rwanda ranks 96 with score 29.3; Tanzania ranks 95 with score 29.4; Uganda ranks 77 with score 38.3 and Angola ranks 88 with score 31.8). The other neighbouring countries, Central Africa and Congo-Brazzaville, have not been taken into account for the GFSI calculations. South Africa belongs to the category of upper middle-income countries, ranks 39 and has a score of 61. Based on the information

given above it is clear that the DR Congo has the worst food security status at this moment in southern Africa.

4. Food Security Status of Households in the DR Congo

In general, cassava and palm oil are the most consumed foods by the households: 85 % and 96 % respectively, and this on average four to five days a week. Cereals (81 %), vegetables (77 %) and meat, poultry, fish and seafood (74 %) are consumed by fewer households and only on average three times a week. The other foods, such as sugars and sugary products and milk and dairy products, are consumed not even by half of the households, and if consumed, only once a week (MICS 2010).

4.1. Geographical Distribution of the Household Food Security

The renewed fighting between the armed forces and the M23 movement in mid-November 2012 contributed to the deterioration of the food security and nutrition situation, especially in North Kivu province. Armed conflict has disrupted trade and resulted in high staple food prices. In November 2012, the nominal retail price of cassava flour increased by 14 % compared to October and by 107 % compared to November 2011. In the provinces of South Kivu, Orientale, Maniema and Katanga, armed conflict continued to displace people and disrupt livelihoods, causing a subsequent deterioration of food security and nutrition conditions. According to the preliminary results of the comprehensive emergency food security assessment (EFSA) [8] conducted by the WFP, FAO and the Ministry of Agriculture in October 2012 in South Kivu, more than 950,000 people (18 %) are affected by severe food insecurity. The nutritional situation remains alarming, particularly in the Minova health zone in South Kivu province, where the rate of global acute malnutrition was found at 10.8 %, according to the results of the nutrition survey conducted by the PRONANUT (*Programme National de Nutrition*) during the last quarter of 2012 (WFP 2013).

Following the index used by the WFP and FAO stating that a household is considered as food insecure if its food consumption score (FCS) (ENA 2013) is less than or equal to 38, the MICS 2010 (tab. 1) identified in the DR Congo an average of 33 % of food-insecure households. The country has four groups of provinces according to the level of food insecurity:

— Group I consists of the city of Kinshasa, with 5 % food-insecure households.

— Group II consists of the provinces with more than 5 but less than 25 % food-insecure households. This group comprises successively Bandundu province, with 19 % food-insecure households; Kasai Occidental province, with 20 % food-insecure households; and the province of Bas-Congo, with 23 % of food-insecure households.
— Group III consists of the provinces where the level of household food insecurity varies between 25 and 50 %: the provinces of Katanga, 29 %; Kasai Oriental, 32 %; Equator, 36 %; and North Kivu, 40 %.
— Group IV consists of the provinces where more than half of the population is food insecure. The provinces of Maniema, with 53 % food-insecure households; the Eastern Province, with 57 % food-insecure households; and the province of South Kivu, with 60 % food-insecure households. According to the MICS 2010 in terms of food insecurity, the DR Congo has an average of 33 % food-insecure households.
— The province of the Equator, which is the greatest area in the Congo River basin, is situated in the area of food insecurity III, with 36 % food-insecure households. Moreover, with the massive influx of refugees, the WFP even thinks that the level of insecurity in the province deteriorates even further.

Table 1
Percentage of household food security situations by province

PROVINCES	SCA* poor	SCA* borderline	SCA* acceptable	No. of surveys
KINSHASA	0.8	4.2	95.0	766
BAS-CONGO	4.7	18.3	77.0	484
BANDUNDU	4.1	15.1	80.8	1,236
EQUATEUR	11.8	24.5	63.7	1,170
ORIENTALE	23.1	34.0	42.9	1,653
NORD KIVU	18.6	20.9	60.5	664
MANIEMA	22.2	30.8	47.0	289
SUD KIVU	33.3	26.7	40.3	544
KATANGA	8.2	21.2	70.6	1,286
KASAI ORIENTAL	10.1	21.9	68.0	1,498
KASAI OCCIDENTAL	5.2	15.0	79.9	1,803
TOTAL	**11.6**	**21.1**	**67.4**	**11,392**

Source: MICS 2010 "*Niveau actuel de l'insécurité alimentaire dans les ménages*", p. 207.

* *Score de Consommation Alimentaire.* Indicator used in many surveys by WFP, FAO, UNICEF and PRONANUT to assess the levels of food consumption within households.

4.2. Rural versus Urban Household Food Security

Living conditions remain precarious for a large part of the population throughout the country, especially in rural areas and in the areas of social insecurity created by wars and armed conflicts, where people, often on the run, lose their livelihoods and undergo constant abuse by armed elements. It is clear that the level of food insecurity is worse in rural areas (39 %) compared to urban areas (19 %) taking into account the level of poor and borderline food insecurity (MICS 2010). According to nutrition surveys conducted in April 2009 by COOPI [9]/PRONANUT in the Congo Basin, and more specifically in the Equator province, a high prevalence of malnutrition was measured in the health areas of Ikela Bokungu and Mondombe with 14.2 % global acute malnutrition and 5.3 % severe acute malnutrition.

Also in urban areas, many households live from day to day, without food reserves. It is estimated that more than half of the urban Congolese live without food supplies or money for their food. Currently, a large proportion of households, even in agricultural provinces, eat only once a day, resulting in malnutrition and low productivity.

In the DR Congo, despite the lack of quantifiable data, we know that most households, especially in suburban areas of large cities, often consume foods with low nutritional value. Even if they have food of high nutritional value (meat, fish), they often sell it to buy non-food items.

Table 2 shows the level of food insecurity in rural and urban areas following the food consumption score in 2010. It is clearly shown that the level of food insecurity is worse in rural areas compared to urban areas.

Table 2
Percentage of food-insecure households in cities and rural areas in the DR Congo, according to MICS (2010)

Poor settlements	SCA poor	SCA borderline	SCA acceptable	No. of surveys
Towns	5.7	13.2	81.1	3,566
Rural areas	14.2	24.7	61.1	7,826

Source: MICS 2010.

5. Food Security Status at Individual Level (fig. 1)

In 2011, 50.4 % of the population had dietary energy consumption below minimum level.

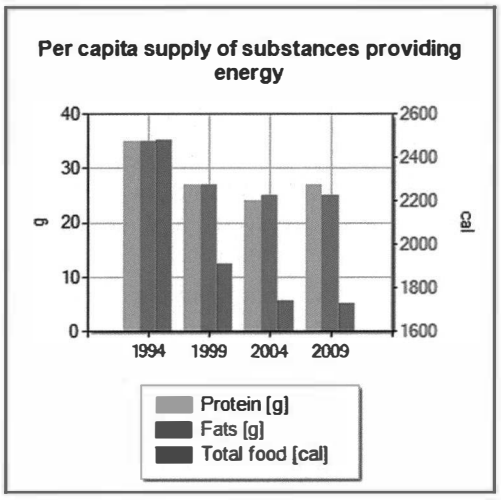


Fig. 1. — DR Congo — *Per capita* supply of substances providing energy 1994-2009 (FAO 2013).

Stunting or chronic malnutrition, as measured by the length/age to -2SD, hit almost one out of two children in the DR Congo. According to the demographic and health survey (DHS) 2007, the overall prevalence of chronic malnutrition (height/age < -2SD) was 47 % (24 % severe form, = <-3SD). This percentage had not changed too much in 2010 as the MICS 2010, published in September 2011, confirmed that the DR Congo is the country in Central Africa with the highest delayed growth. Stunting or chronic malnutrition affects 43 % at the national level for children under five years. The three provinces that make up the Congo basin, namely Equator and the two Kasai, have an average of 41 % growth retardation as a whole. Underweight (weight-for-age less than -2 standard deviation) in turn, affects one child out of four, or 24 %. Acute malnutrition (weight-for-height less than -2SD) affects 11 % of the children under five years at the national level.

In terms of absolute numbers, the prevalence of wasting results in more than one million children affected by acute malnutrition needing support and the prevalence of stunting results in more than six million Congolese children with delayed growth.

The DR Congo faces serious nutritional problems. According to various surveys and studies, these issues are complex and vary from one province to another. They affect not only young children, but also adults, especially pregnant and lactating women, and displaced populations.

The analysis of these data in the DHS 2007 reveals significant disparities in child malnutrition between different provinces. Regarding acute malnutrition, the most affected are the two Kasai provinces (16 %), Katanga (15 %) and Equator (15 %). If we consider growth retardation, three provinces accuse rates above 50 %, namely North Kivu, South Kivu and Equateur.

Underweight (fig. 2), measured by weight/age index below -2SD, being a millennium development goal (MDG) indicator in the field of nutrition, is widespread in the country. It affects one out of four children in the DR Congo, a prevalence of 24 %.

Figure 3 shows the malnutrition trends among children less than five years old between 2001 and 2010.

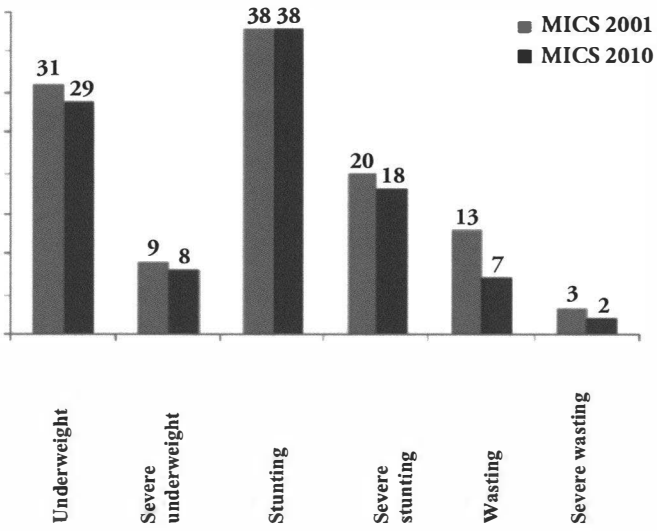
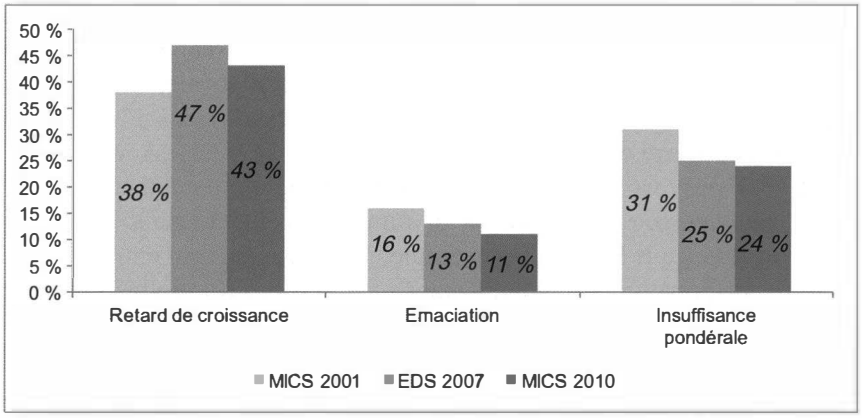


Fig. 2. — Malnutrition trends among children under five years old between 2001 and 2010 (ref. NCHS/CDC/WHO of 1977) (ref. NCHS/CDC/WHO of 2007).



Source: PRONANUT: *Compilation des données des enquêtes nutritionnelles de 2000 à 2012.*

Fig 3. — Prevalence of different forms of malnutrition in children of less than five years old according to MICS 1, DHS 2007 and MICS 2010.

Deficiencies in essential micronutrients for survival (especially vitamin A and iron) are widespread in the country. With regard to vitamin A, a severe deficiency affects the Congolese population, as a national study conducted by PRONANUT, with support of UNICEF, in 1998 reveals a mean prevalence of 61.1 % among children under five (PRONANUT 2000).

Regarding anemia, 71 % of the children under five and 53 % of the women of reproductive age (19-49 years) are affected. The chronic form of anemia results not only from iron deficiency but is compounded by the effect of many infectious and parasitic diseases, including malaria and intestinal parasites especially in children. About anemia, a study conducted by UNICEF and PRONANUT showed that 82 % of the children are affected by anemia (PRONANUT 2005).

6. Correlates of Food Security in the DR Congo

6.1. Poverty

The DR Congo belongs to the category of low-income countries (<= US$ 1,005/person/day (WB 2011)). It scores 18.4/100 following the GFSI ranking tables, and has therefore the lowest position rank of 24 out of 24 low-income countries (EIU 2013). The food insecurity situation cannot be separated from one of its main causes, which is poverty.

The National Agricultural Investment Plan (PNIA) 2013-2020 of the DR Congo states that the DR Congo is one of the African countries with the highest incidence of poverty. The DR Congo, with a poverty incidence of 71.34 % (*Ministère de l'Agriculture et Développement Rural*, PNIA 2013-2020) for the entire country, is the poorest country of Central Africa. The extent of poverty varies considerably from one region to another, depending on whether you live in urban or rural areas. In the rural areas, the poverty incidence is higher. For example, in some territorial entities in the provinces of Equator, Maniema, Katanga and Eastern Kasai, the incidence of poverty exceeds 85 %. The extent also varies among the occupational groups (independent workers and apprentices are the poorest, with 77 %, followed by labourers, employees and semi-skilled workers, with 66 %). Poverty extensively affects households where the head is between thirty and sixty-five years old. The DR Congo is therefore living in a vicious circle of poverty, food insecurity and malnutrition (PNIA 2013, p. 5).

The result of this is the failure to meet the basic needs of the population. Therefore, it requires vigorous reforms in the agricultural and economic sectors and consideration of nutrition to allow the reduction of poverty.

6.2. Agricultural Information

Agriculture accounts for 42.5 % of the DR Congo's gross domestic product, employs 62 % of its men and 84 % of its women, and is the country's most promising foundation for establishing food security and sustainable, equitable economic development (USAID 2013).

Food production and agricultural production *per capita* (tab. 3) have been steadily decreasing since 1996, but since 2006 the decline is getting smaller (from -3.5 and -3.64 to -0.62 annual growth rates). The agricultural production per agricultural worker has increased, but unfortunately fewer and fewer people are involved in agriculture. The total area under cultivation has not changed (FAO). The evolution of the land use (1996-2011) is given in table 4.

The foods, for which the main source of availability comes from own household production, are roots and tubers (63 % of the households), fruits (50 %), corn (48 %), vegetables (46 %) and oilseeds (70 %). Other foods are mainly obtained by purchases at the market, especially in large cities. These foods are milk (93 %), sugar (91 %), rice (70 %), palm oil (69 %), meat (68 %) and legumes (58 %). Own household production and other food sources are unable to meet the food needs of the majority of the households, leaving the country still in a state of food insecurity (MICS 2010, p. 2007).

Table 3
DR Congo: evolution of the food and agricultural production *per capita* (1996-2011)

Index of *per capita* production							
	Gross PIN* [base 2004-2006]				Annual growth rate [%]		
	1996	2001	2006	2011	1996-2001	2001-2006	2006-2011
Food production *per capita*	135	113	98	95	- 3.50	- 2.81	- 0.62
Agricultural production *per capita*	136	113	98	95	- 3.64	- 2.81	- 0.62
Agricultural production per agricultural worker	126	109	98	101	- 2.86	- 2.11	0.6

Source: FAO 2011.

* *Produit intérieur* (domestic product).

Table 4
DR Congo: evolution of land use (1996-2011)

Evolution of land use							
	Area [millions of ha]				Annual growth rate [%]		
	1996	2001	2006	2011	1996-2001	2001-2006	2006-2011
Total area	226,71	226,71	226,71	226,71	0	0	0
Arable land	6,70	6,70	6,70	6,80	0	0	0.30
Permanent crops	1,00	0,75	0,75	0,76	- 5.59	0	0.27
Forest cover	158,49	156,94	155,38	153,82	- 0.20	- 0.2	- 0.20

Source: FAO 2011.

Cassava is by far the most important food crop in the DR Congo; it occupies an area of about 2 million hectares and since 2002, the annual production is about 15 million tons. The national demand for cassava is about 70 % of the total demand for foods consumed and domestically produced. Banana is the second culture in the country after cassava from the point of view of production and demand. The total production of bananas and other fruits has reached an average value of 4.1 million tons, of which 47 % for various banana products: plantain (25 %), sweet (8 %) and beer production (14 %). Cereals come third, with a total average annual production of about 1.55 million tons: 74 % corn, 23 % rice, 3 % millet and 1 % wheat. As for

pulses, the average production in absolute terms over a period of 16 years (1991 to 2006) is 670,681 tons, of which 64 % for peanuts, 20 % for beans, 7 % for cowpea and 5 % for squash. Vegetables are very important in volume consumed (24.35 kg/head in 2000 in Kinshasa) (ESA 2009).

According to the National Agricultural Investment Plan (PNIA 2013), traditional agriculture, also known as family farming, counts for more than 80 % of the national production. Small farms use rudimentary tools and the workforce is mainly composed of members of the household. Peasant households mainly cultivate to ensure the food self-sufficiency of their families and have a small but relatively diverse production, consisting of cassava, maize, rice, vegetables and fruits. In the eastern provinces, traditional agriculture is often associated with livestock, households owning mostly small ruminants — sheep and goats — and a good portion of pigs and poultry. Family farmers also produce more than 80 % of the country's fishery resources. The number of smallholder households at national level is estimated at 6 million, with an area of 8,000,000 hectares (meaning an average area per holding and per household of 1 to 1.5 hectares) (PNIA 2013).

Modern agriculture, practiced by agribusiness companies, is mainly producing export crops: coffee, rubber, cocoa, tea, palm oil and cinchona. Some crops, such as sugar cane, cotton and tobacco, are used locally. This type of agriculture has suffered from several political crises that have marked the history of the DR Congo. Most of the industrial production have experienced setbacks and exist only by name. Most agro-industrial units are destroyed and investments for relaunch are rare.

Due to the absence or inefficiency of national development, the supervision of farmers was ensured in practice either by religious organizations and cooperatives, or by some private companies abutting the few players present in rural areas. Where these actions were successful, traditional agriculture has given way to group farming, which is an intermediate phase between traditional and modern agriculture and the result of the awareness of the best farmers of the richness of the soils.

7. Ongoing Strategies

The DR Congo has developed a National Agricultural Investment Plan (PNIA 2013) for 2013 to 2020, in which it pays more importance to group farming, as it allows moving from traditional to modern agriculture. The DR Congo needs this form of agriculture not only for government actions (rural

development projects, agricultural commissions) but also to compete with several missionaries and private operators. Group agriculture is charged to ensure the dissemination of modern agricultural techniques and stimulate traditional neighbouring farmers.

In 2010, the DR Congo has developed its national programme for food security (NPFS), called PNSA (*programme national de sécurité alimentaire*). The overall objective of the PNSA is to contribute in a sustainable way to the fight against food insecurity and improve the living conditions of the populations by increased production and household income.

The specific objective of this programme is to improve the food security of the vulnerable areas with the following actions:

— Increase the volume of agricultural production through improved productivity, product diversification and security of production systems;
— Promote (valorize) agricultural crops, fisheries, livestock and non-timber forest products by improving post-harvest storage and processing techniques;
— Improve access to food and the nutritional and health (sanitary) status of the populations;
— Strengthen the capacity of support structures for the producers.

However, it should be noted that since its inception, the NPFS (PNSA) has never received any funding; on the contrary, the Government has recently set up another programme at provincial level to relaunch their food crop productions. All this leads many observers to notice that the Congolese agriculture suffers from an abundance of well-made texts, never implemented due to high dependence on outside funding.

8. Conclusion: What is the Road forward?

An answer should be found to the questions what the role of the government and what the role of the households is.

The State is at the centre of all governance, but what about its administrative and political capacity?

The main problems are:

— A lack of political will to take into account the complexity of food systems with food security as an outcome. How to put food security higher

in the hierarchy of priorities and how to overcome the bureaucratic and organizational hurdles.
— Limited actions of the civil society.
— Limited actions of the private sector.
— Lack of purchasing power.
— Underperforming agriculture.
— Managing nutrition transition by rebuilding local food systems and the strength of links between local small-scale producers and urban consumers.
— Long-term actions should focus on agricultural models that do not use costly input.

Possible actions are:

A. Increase food availability:
Increase agricultural production by increased arable land, proper use of water, minimizing post-harvest losses, improved access to Credit, more entrants at reasonable prices, better extension services, ...
B. Increase food accessibility:
   - Create job opportunities;
   - Make food available at local markets (better infrastructure, transport and storage facilities).
C. Increase food stability:
   - Appropriate processing techniques, *e.g.*, to make vegetables and fruits available the whole year round;
   - Proper storage facilities at household, village and/or district level;
   - Better price control.
D. Better food utilization through household:
   - Nutrition education (choice of food, cooking, intra household distribution, proper preservation, frequency of meals, ...);
   - Better access to health facilities;
   - Access to safe water.

NOTES

[1] Multiple Indicator Cluster Survey (MICS-UNICEF) (in French: *Enquête par grappes à indicateurs multiples*): national survey conducted since 1996 every five years by the Ministry of Plan with the financial support of several partners, mainly UNICEF. The goal of this study is to have a mirror of indicators on several domains: health, education, nutrition, food security. The last MICS was done in 2010.

[2] Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Household food security is the application of this concept to the family level, with individuals within households as the focus of concern. Food insecurity exists when people do not have adequate physical, social or economic access to food as defined above.
[3] The weight and height of children between six and fifty-nine months is used as a proxy for the health of the population as a whole in protracted refugee situations.
[4] *Medecins Sans Frontières.*
[5] (http://www.wfp.org/countries/Congo-democratic-republic-of/food-security)
[6] The Global Hunger Index (GHI) is designed to comprehensively measure and track hunger globally and by country and region; it is calculated each year by the International Food Policy Research Institute (IFPRI). To reflect the multidimensional nature of hunger, the GHI combines three equally weighted indicators in one index number: undernourishment; child underweight and child mortality (http://www.ifpri.org/book-8018/ourwork/researcharea/global-hunger-index)
[7] Weighted total of all category scores (0-100, where 100=most favourable).
[8] An EFSA answers the following key questions: does the crisis have an impact on the population's food security and livelihoods? How severe is the situation? Has the level of malnutrition been exacerbated by the crisis? How are people coping? How many people are food insecure and where are they? http://www.wfp.org/food-security/assessments/emergency-food-security-assessment
[9] Italian Cooperation.

REFERENCES

COOPI/PRONANUT Résultats des enquêtes territoriales dans la province de l'Equateur, April 2009.
COOPI/PRONANUT 2013. Résultats des enquêtes territoriales dans la province de l'Equateur, April 2009.
DHS 2007. Demographic and health survey 2007.
EFSA 2013. http://www.wfp.org/food-security/assessments/emergency-food-security-assessment
EIU 2013. http://foodsecurityindex.eiu.com; https://www.eiu.com/public/topical_report.aspx?campaignid=FoodSecurity2013
ENA (Emergency Needs Assessments) 2013. http://home.wfp.org/stellent/groups/public/documents/ena/wfp196627.pdf
ESA 2009. Etude du Secteur agricole: Rapport (ESA) bilan diagnostic et Note d'orientation, juin 2009.
FAO 2006. http://www.fao.org/docrep/003/w3613e/w3613e00.htm
FAO 2010. http://www.fao.org/docrep/013/i1683e/i1683e.pdf — WFPorg/FAO — The state of food insecurity in the world 2010 — Addressing food insecurity in protracted crises. FAO 2010.
FAO 2011. http://faostat.fao.org
FAO 2013. http://faostat.fao.org

IFPRI 2012. http://www.foodsecurityportal.org/dr-Congo?print
MICS 2010. http://www.childinfo.org/files/MICSRDC_2010_Preliminary_Results_final_EN_ imprime.pdf
PNIA 2013. Ministry of Agriculture, "Plan national d'investissement agricole (PNIA) 2013-2020".
PNSA 2011. http://lavoixdupaysanCongolais.files.wordpress.com/2012/02/rdc-programme-national-de-sc3a9curitc3a9-alimentaire-janvier-2011.pdf
PRONANUT 2000. Rapport de l'Enquête Nationale sur la carence en vitamine A en RDC.
PRONANUT 2005. Enquête sur l'anémie en RDC.
TOLLENS, E. 2003. L'état actuel de la sécurité alimentaire en R.D. Congo: Diagnostic et perspectives. De l'aide humanitaire d'urgence au développement durable de l'agriculture pour une meilleure sécurité alimentaire en République Démocratique du Congo. — Kinshasa, Alliance Belgo Congolaise, Gombe.
WB (World Bank) 2011. World Development Report 2011. http://worldbank.org/INTWDRS/Resources/WDR2011_Full_Text.pdf
WFP 2012. Country Summaries — Annex to the global food security update — December 2012.
WFP 2013. Country Summaries — Annex to the global food security update — Issue 9 February 2013.
WFP 2013. Country Summaries — Annex to the global food security update — June 2013.
USAID 2013. http://www.usaid.gov/democratic-republic-Congo/agriculture-and-food-security

POSTERS

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Food Markets and People's Nutrition in the DRC (2004-5)

by

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KEYWORDS. — Food Markets; Nutrition; 1-2-3 Survey; Democratic Republic of Congo.

SUMMARY. — Inspired by the upcoming process of decentralization and relying mainly on the 1-2-3 Survey data (2004-5), this poster provides a comprehensive geographical overview of Congo's food markets as well as the nutritional status of its population. Along both dimensions, a good deal of spatial variation exists. To begin with, overall integration of domestic food markets seems to be extremely poor. Exemplary of this is Kinshasa, being food deficient, poorly connected to its own hinterland and therefore highly dependent on foreign food imports. Markets in Kasaï and the conflict-prone north-eastern part of the country are two minor exceptions, as food prices are slightly flatter. Furthermore, the most competitive food producers are to be found in Equateur and North Kivu. Notwithstanding this differential access to food, about five diet types can be identified. The most nutritious diet is that which is based on cassava and palm oil, typically consumed in Maniema, Orientale, Equateur and (rural) Bas-Congo. As a result, these provinces on average display higher calorie intakes. Apart from diet composition, income levels and prevailing non-food needs also determine people's nutritional sufficiency. For these reasons people in Katanga and North Kivu are relatively well nourished too, while urban dwellers in Bas-Congo and Orientale (contrary to their corresponding rural sector), and especially the inhabitants of South Kivu and Kinshasa, suffer from large calorie deficiencies.

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Understanding Major Determinants for Fertilizer Use in South Kivu, DR Congo

by

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KEYWORDS. — Fertilizer Use; Smallholders; Determinant; Technology; DR Congo.
SUMMARY. — Although increasing inorganic fertilizer use is recognized as a key strategy for increasing smallholder farms' productivity, eastern DR Congo's smallholder agricultural sector continues to register one of the lowest fertilizer use levels in sub-Saharan Africa. To develop the appropriate soil fertility management approaches in the region, a VLIR-UOS project develops activities towards the use of microdoses of fertilizer as part of Integrated Soil Fertility Management (ISFM). The promotion of increased adoption for improved agricultural technologies, such as inorganic fertilizer use, will be pursued as a strategy to revitalize the agricultural sector. This study focuses on socio-economic issues which determine both organic and inorganic fertilizer use by smallholder farmers in the South Kivu region. A survey of determinants of fertilizer use was administered to eight hundred farmers who were randomly selected from villages within six AfSIS sentinel sites in the project research area. Results from the collected data have shown that organic fertilizers are common to farmers and more used than inorganic fertilizers. Characteristics of households were analysed and disaggregated by fertilizer use or non-use. On the one hand, the results showed that at household level, land and livestock ownership, an age below fifty years of the household leader, poor soil type, higher level of education and access to fertilizers had a positive effect on fertilizer use. On the other hand, gender (household leader being a woman), size of the household (the number of children), non involvement in rural development organizations, small size of farms, the fact that farmers are price-takers when selling their products, high fertilizer prices and

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lack of extension and credit programmes regarding fertilizers proved to be negatively correlated with fertilizer use.

Although fertilizer use may be profitable for smallholder farmers, subsistence priorities, low agricultural infrastructures, low investment in fertilizer's marketing and distribution may turn farmers away from using fertilizers. Developing sustainable, competitive input supply and output marketing systems might be essential for increasing and stimulating fertilizer use.

Biological Aspects

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Conservation and Utilization of Wildlife in the Congo Basin: How to tackle the Protein Gap?

by

Robert NASI*, N. VAN VLIET & M. PINEDO-VASQUEZ

KEYWORDS. — Bushmeat; Biodiversity; Livelihoods; Forest; Congo Basin.

SUMMARY.** — Protein from forest wildlife is crucial to rural food security and livelihood across the tropics. The harvest of animals such as duikers, antelopes, pigs, primates, rodents, birds and reptiles provides benefits to local people worth millions of US$ annually and represents around six million tonnes of animals extracted yearly. Vulnerability to hunting varies, with some species sustaining populations in heavily hunted secondary habitats, while others require intact forests with minimal harvesting to maintain healthy populations. Some species or groups have been characterized as ecosystem engineers and ecological keystone species. They affect plant distribution and structure ecosystems, through seed dispersal and predation, grazing, browsing, rooting and other mechanisms. Global attention has been drawn to their loss through debates regarding bushmeat, the "empty forest" syndrome and their ecological importance. However, information on the harvest remains fragmentary, along with understanding of ecological, socio-economic and cultural dimensions. Here we assess the consequences, both for ecosystems and local livelihood, of the loss of these species in the Congo Basin and propose alternative management options.

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** PowerPoint presentation: cf. CD-ROM. Links to open access documents: http://www.cifor.org/publications/pdf_files/articles/ANasi1101.pdf and http://www.observatoire-comifac.net/docs/edf2010/FR/EDF_2010_FR_06.pdf

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Edible Mushrooms of Kimvula City in Lower Congo (DR Congo)

by

Simon DIBALUKA MPULUSU*, Félicien LUKOKI LUYEYE*,
Jan RAMMELOO** & Jérôme DEGREEF**

KEYWORDS. — Edible Mushrooms; Kimvula; DR Congo.

SUMMARY. — Kimvula city is located in the transition zone between Guineo-Congolese and Zambezian regions. Its geographic coordinates are 5°43' South and 15°57' East. It lies in a valley, more or less 570 m high, surrounded by hills more or less 600 to 650 m above sea level and behind them are mountain ranges, *i.e.* isolated mountains (or hills) in the shape of an "inselberg", which are situated in the largest areas of woodland up to more or less 800-850 m.

Of the 131 taxa inventoried in the study area, 79 are edible and 6 are medicinal. These taxa were collected primarily in three vegetation types: woodland, gallery forest and savannah. Among the 79 edible taxa, 63 were found in woodland, with only 54 taxa in woodland alone and 9 both in woodland and in other habitats. In the gallery forest, there were only 9 taxa of which 6 were found strictly in the gallery forest and 3 also in other habitats. Savannah is also a very favourable environment for the growth of *macrofungi*, especially those belonging to the genus *Termitomyces*; we collected 10 taxa of which only 4 were found in savannah and 6 both in savannah and other habitats. Some taxa were collected outside the three main vegetations, in residential parcels for example. In this group we counted 11 taxa of which 4 are shared between these habitats and the vegetation above.

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Edible Lignicolous Mushroom Cultivation of Kimvula City in Lower Congo (DR Congo)

by

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KEYWORDS. — Edible Mushrooms; Cultivation; DR Congo.

SUMMARY. — Some edible lignicolous species were selected for *ex situ* cultivation test. A preliminary step was to identify, with local populations, lignicolous species which are most widely eaten. The choice of species to grow was based on the results of a survey conducted in the ethnomycological medium study in the city of Kimvula and its surroundings. Seventeen strains of edible wood fungi isolated on agar medium and then selected according to criteria previously established (including mycelial growth speed) were tested on substrates seed-based corn and sawdust substrates. The fruiting step was carried on substrates based on sawdust, *Cyperus papyrus* stalks, sugar cane bagasse and wild grasses straws. Those substrates yielded encouraging results. From 17 strains isolated, 14 were selected to produce culture, the hard white, specially on corn grain and sawdust. The mycelia of all strains invaded the corn for a time ranging between 8 and 21 days. The strain (010408) of *Lentinus sajor-caju* invaded the corn faster (8-10 days) than all other strains, the invasion of which was the slowest (21 days) in *Auricularia cornea* (strain A2255) and *Marasmiellus inoderma* (strain 171107). The mycelia obtained from the corn kernels were used to inoculate the seed with sawdust substrate. Incubation of sawdust lasted 21 to 40 days, with the exception of strain 080408 *Marasmiellus inoderma*, for which the total invasion of the substrate took place after more than 90 days of incubation. On the sawdust, the mycelium has been well preserved at room temperature (28-32 °C) for more than six months, while the corn kernels have preserved the purity and viability and the strength of the mycelium in these conditions. Average yields of fruiting bodies varied between 9.7 and 27 % on the different substrates tested. Substrates sawdust gave the highest yields in their formulas (For8 and For16), specially for *Pleurotus* strains, with an average yield of 25.6 % (± 3.4) on the formula 8, for the *Pleurotus cystidiosus* 170408 and 24.3 % (± 2.0) for the strain of *Pleurotus flabellatus* 250,208 and an average yield of For16 22.7 % (± 1.6) for the strain of *Pleurotus cystidiosus*

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170,408 and 27.0 % (± 1.4) for the strain of *Pleurotus flabellatus* 250,208. Sawdust in its formula For8 also gave good returns for the strain of *Auricularia cornea* is 011,208 yields ranging between 9.6 and 26.7 %. However, LS2255 *Lentinus squarrosulus* strain gave the best performance on the sawdust: S1 yielded 19.1 % (± 1.9). On grass straws, bests performances were respectively 20,9 % (± 2,9) for 170408 *Pleurotus cystidiosus* strain on *Digitaria polybotrya* substrate (For9) and 21,1 % (±3,7) on *Hyparrhenia diplandra* (For13).

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Safeguarding Traditional Knowledge of Wild Edible Plants and Mushrooms in Bayaka Communities (Republic of Congo)

by

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KEYWORDS. — Ancestral Knowledge; Bayaka Communities; Plants; Mushrooms.

SUMMARY. — The forest of the Republic of Congo is part of the Congo Basin forest, which is recognized worldwide for its high biodiversity and as the second largest dense tropical rainforest after Amazonia (DEVERS 2006). Some areas of this forest, which have been studied because of the importance of large mammals, led to the creation of landscapes highlighting the ecological value of these areas. In 2002, *e.g.* the Sangha-Trinational landscape (STN) was created and recognized as an important area for conservation purposes covering over 96 % of intact forest out of its total area (CARPE 2005).

Despite the richness these forests have in terms of plants and mushrooms, and while many people rely on natural resources for their livelihood, detailed information on non-timber forest products used by Bayaka Communities in the Congo Basin is rare or not available (LETOUZEY 1976, MOTTE 1980, MALAISSE *et al.* 2008, EYI NDONG *et al.* 2011). All over the world, this knowledge is critically endangered because of the change in both environment and culture (SHENGJI 2003). Being aware that local people are "carriers of ancestral knowledge and wisdom about this biodiversity" (SOBREVILA 2008), the "Initiative for Mushrooms and Plants of Congo" (IMPC) was created to highlight and safeguard ancestral knowledge and document useful plants and mushrooms in the Republic of Congo. For six years (from 2008 to 2013), we have been working in close relationship with two Bayaka Communities (Mbenzele and Ngombe) in northern Congo to gather information on the use of plants and mushrooms.

Preliminary results of our field inventories are here presented and related to ethnobotanical and -mycological data obtained from the two communities.

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REFERENCES

CARPE 2005. The Forests of the Congo Basin: a preliminary assessment. — The Congo Basin Forest Partnership.

DEVERS, D. 2006. The forests of the Congo Basin: State of the Forest. — The Congo Basin Forest Partnership.

EYI NDONG, H., DEGREEF, J. & DE KESEL, A. 2011. Champignons comestibles des forêts denses d'Afrique centrale. Taxonomie et identification. Abc Taxa, 10, 253 pp.

LETOUZEY, R. 1976. Contribution de la Botanique au problème d'une éventuelle Langue Pygmée. — Paris, SELAF.

MALAISSE, F., DE KESEL, A., N'GASSE, G. & LOGNAY, G. 2008. Diversité des champignons consommés par les pygmées Bofi de la Lobaye en République Centrafricaine. — *Geo-Eco-Trop*, **28**: 1-11.

MOTTE, E. 1980. Les plantes chez les Pygmées Aka et les Monzombo de la Lobaye (Centrafrique). — Paris, SELAF.

SHENGJI, P. 2003. The Role of Ethnobotany in the Conservation of Biodiversity. — *In*: LEE, C. & WANCHOPE, S. (Eds), The importance of sacred natural sites for biodiversity conservation, pp. 119-126. Paris, UNESCO.

SOBREVILA, C. 2008. The Role of Indigenous Peoples in Biodiversity Conservation. The Natural but Often Forgotten Partners. — Washington DC, World Bank.

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Wild Edible Plant Use in Tshopo District, DR Congo

by

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KEYWORDS. — Wild Edible Plants; Nutrition; Ethnobotany; Market Potential; DR Congo.

SUMMARY. — Tshopo District has an enormous agricultural potential, but food security remains precarious. Despite the enormous richness in biodiversity and cultures, wild edible plants (WEPs) have little been studied in Tshopo District, c.q. DRC. The objective of this study was to contribute to the valorization of WEPs for better nutrition security, higher and more diversified farmer's incomes and sustained cultural well-being. From 2004 till 2011, Kisangani University, together with Ghent University, carried out a WEP project with as research questions: 1) What are the WEPs known and used in Tshopo District?; 2) How are they used? Which WEPs are most appreciated?; 3) What is the actual and potential contribution to local diets?; 4) What is the actual and future commercial potential?; 5) How can WEPs be better valorized? What are the priority species for promotion, (participatory) domestication and market chain organization?

An ethnobotanical inventory within three ethnic groups (Turumbu, Mbole and Bali) in three different territories of the district documented 166 WEP species and 2 varieties from which 198 plant parts are used for 228 different food uses. Preferences in taste and commercial, nutritional and cultural value of WEPs were discussed during participatory ranking exercises. WEP markets in Kisangani were analysed in relation to number and characteristics of sellers, species and quantities offered, prices and periodicity. Only 15 WEPs were seen to be sold on Kisangani markets by a small number of '*ad hoc*' traders, who easily switch to other products. Although a certain form of organization was found in the *Gnetum africanum* trade with Kinshasa as main destination, other WEP markets in the region remain underdeveloped. To assess the contribution of WEPs to dietary quality, the usual dietary intake of 363 urban and 129 rural women was assessed within the period of highest WEP availability (August-September). Contrarily to what was expected, only 15 WEPs were found to occur in a marginal number of 24h recalls. The most noteworthy contribution came from the semi-wild safou fruit (*Dacryodes edulis).* The total energy intake

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of the women was rather low, with a high percentage energy coming from fats. Micronutrients of major concern were niacin, folate, vitamin B-12, iron, zinc and calcium, with more than 75 % of the women having intakes below the recommended dietary allowances. Despite the precarious nutrition security, urban as well as rural inhabitants in this biodiverse region do not valorize their knowledge on WEPs to complement their diets.

Promotion of WEPs alone will not solve all underlying causes of nutrition insecurity and poverty in the region, but WEPs could at least contribute more to diets and incomes then they currently do. A lot of WEPs with proven nutritional qualities, such as *Gnetum africanum* and *Treculia africana*, are present in the region. Lack of nutritional and health information on WEPs was frequently mentioned as constraint for WEP consumption. Before getting lost, local knowledge on WEPs and their dietary use needs further research to capture the potential of biodiversity and ameliorate diet adequacy. Furthermore, it should be possible to identify, embrace and build upon local socio-cultural values to enhance WEP consumption and trade. Nutritional education messages should be based on sound scientific knowledge, while able to stimulate local positive behaviours. We recommend the integration of WEPs into strategies for sustainable rural development in Tshopo District, *e.g.* through promotion of homegardens and integration of WEPs in these systems. Research into agro-biodiversity and agroforestry starting from local needs and indigenous knowledge, and backed up by sound scientific research is indispensable to create innovative, resilient agricultural models able to produce healthy foods in a sustainable way while at the same time conserving biodiversity for future generations.

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Valorization of the Indigenous Knowledge of the Melliferous Plants in the Vicinity of the Virunga National Park (DRC) to contribute to an Enhancement of its Conservation

by

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KEYWORDS. — Beekeeping; Conservation; Melliferous Plants; Virunga National Park.

SUMMARY. — An investigation on the knowledge of the melliferous plants by the inhabitants of the Rugari area was completed in 2009. This region, located in the eastern part of the DR Congo, partially includes the southern sector of the Virunga National Park (VNP).

The objective of the research was to increase interest in these plants in order to promote the conservation of their habitats and of the park itself. Indeed, this protected area has been altered to the point it was declared by UNESCO as a World Heritage in Danger in 1994.

The interview involved 120 people, including 50 beekeepers. The specimens of melliferous plants recognized by the inhabitants were collected to confirm their identification. We referred in particular to the herbarium of the Institute of Scientific Research in Central Africa (IRSAC), Lwiro.

The analysis of all data generated a list of 152 plant species. They were recognized as melliferous because they were really visited by bees. Among these species, 65.8 % were wild plants.

The hives were located mainly in forests and sometimes in wasteland. Up to 100 litres of honey/year could be harvested by each beekeeper, who could thus get 500 USD additionally to the earnings from his other occupations, especially subsistence agriculture. This is very important, especially as the average *per capita* income is more or less $ 1/day in this region.

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Apart from the evidence that plants pollinated by bees are the source of honey and that this resource contributes much to alleviate poverty, the study can be used to remind people who live near the park the following other realities: the majority of the plants inventoried are wild; without this category of species, the production of honey would be very low; bees would not be strong enough to ensure good pollination; the subsistence or commercial agriculture would give very low yields.

For these reasons, melliferous plants are to be safeguarded. This depends on the conservation of the entire habitats to which the targeted species belong. The beekeeper is an interested actor who is allegedly involved in such an initiative.

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Birds as Food in Africa: Some Reflections

by

Michel LOUETTE*

KEYWORDS. — Birds; Human Consumption; Conservation; Domestication.

SUMMARY. — Africa hosts about 2,000 bird species. Some are counted in millions, others are rare. Wild bird consumption is a protein source for millions of rural people (see *e.g.* BRASHARES *et al.* 2011). On the other hand, eating wild birds can cause health problems: some migratory birds, and bush meat in general, are known to be potential vectors of viruses for humans. Some birds, such as Spur-winged Goose *Plectropterus gambensis* and Common Quail *Coturnix coturnix,* are known to be poisonous to eat during certain periods of the year.

Is exploitation of wild birds a "renewable resource" or, on the contrary, a deplorable act, violating conservation of biodiversity? Hunting wild birds for food in Africa is mostly uncontrolled, occurs on a large scale, and the impacts are not well documented. Although some species, such as the Red-billed Quelea *Quelea quelea* (maybe the most abundant bird species in the world and a local pest to agriculture), no doubt could well be exploited, it is certain that poaching can lead to local extinctions and could exterminate the rarer, larger and less widespread species. Studies note an acceleration and extend in scale and efficiency of wildlife harvest in several African countries. STEVEN *et al.* (2013) show that many bird populations worldwide are at risk of extinction and rely heavily on protected area networks for their continued conservation.

No doubt tourism to Africa is a powerful potential generator of revenue, exceeding the value of bush meat for food. The contribution of tourism revenue for bird species in the IUCN Red List is highest in South America, Africa, and their neighbouring islands. Many protected areas could enhance their management budgets by promoting birdwatching tourism specifically. It is dramatic that this possibility remains wishful thinking in countries with such a high avian biodiversity as the DR Congo.

What about controlled hunting? In South Africa, legal hunting was studied (potential of some birds as a renewable resource). At the University of Cape Town, CROWE (2009 and other papers) found that particular game birds thrive in moderate to heavily

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disturbed landscapes, mainly agriculture, and he calculated that hunting of one species of francolin *Francolinus* yields R360 000 annually in gross revenue, giving significant incentive for farmers to conserve habitat for this bird. But this message is difficult to spread and law enforcement is problematic in Africa in general.

Which species are targeted? Larger species are likely to be preferred but occur in low density, and they are more threatened. There may be local differences in choice of target (*e.g.* a local taboo on hunting the Congo Peacock *Afropavo congensis*, a species heavily exploited in most other areas) (MULOTWA 2009). Some bird species are known to taste better than others and are probably preferred.

Many Palearctic birds migrate to Africa and pass bottlenecks on their migration, where large proportions of the world population falls victim to local hunters. The NGO BirdLife International has a joint programme with hunter federations in North Africa called "Building Capacity for Sustainable Hunting of Migratory Birds" (www.birdlife.org/action/change/sustainable_hunting/).

What about domesticated bird meat? Although the Chicken is omnipresent, the continent is a mass importer of chicken meat. Local raising should be encouraged and modernized. Only two species of African birds were fully domesticated: the Ostrich *Struthio camelus* and the Helmeted Guineafowl *Numida meleagris*. No new candidate for domestication for food in Africa is plausible.

REFERENCES

BRASHARES, J. S., GOLDEN, C. D., WEINBAUM, K. Z., BARRETT, C. B. & OKELLO, G. V. 2011. Economic and geographic drivers of wildlife consumption in rural Africa. — *PNAS*, **108**: 13931-13936.

CROWE, T. 2009. Management of southern African gamebirds: opportunities and threats. — Athens, Warnell School of Forestry and Natural Resources.

MULOTWA, E. 2009. Ecologie du Paon congolais *Afropavo congensis* Chapin en vue de sa conservation. — RD Congo, Université de Kisangani, Thèse de doctorat.

STEVEN, R., CASTLEY, J. G. & BUCKLEY, R. 2013. Tourism Revenue as a Conservation Tool for Threatened Birds in Protected Areas. — PLoS ONE, **8** (5): e62598. Doi:10.1371/journal.pone.0062598.

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Bushmeat Consumption in Households from Brazzaville, Republic of Congo

by

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KEYWORDS. — Bushmeat; Republic of Congo.

SUMMARY. — With 4.9 million tons annually extracted from Central African forests and an offtake rate which may vary between 50 and 897 kg/km²/year, bushmeat largely contributes to meeting the needs for meat-based food among most families residing in the Congo Basin.

The average daily bushmeat consumption *per capita* was estimated at 14 ± 34 g and the total annual consumption in Brazzaville at 5,121 t.

Quantitative and qualitative surveys of the bushmeat consumption were undertaken in Brazzaville in 2006, in about 1,050 urban households.

The results showed that 88.3 % of the surveyed households consumed bushmeat. Their average size was 5.7 ± 3.2 persons. The average monthly income of an urban consumer with a permanent job was 98,334 ± 84,306 FCFA (US$ 197 ± 169). Meat from mammals was preferred, the top three orders of this class being artiodactyls (48.3 %), rodents (28.3 %) and primates (13.0 %). Some of them are listed as threatened in Congo Brazzaville and are included in the IUCN Red List. The results showed that in Brazzaville bushmeat consumption remains important and is determined by socio-economic parameters.

The factors which determine demands for bushmeat are tradition and taste. That demand has a negative impact on populations of some mammal species, such as forest buffalo, red river hog and forest elephant, which are now seldom seen around Brazzaville, particularly in the southern pool district. This survey highlights the importance of implementing a new forest policy involving local people in the sustainable management of protected areas and hunting zones.

A survey of the bushmeat trade was undertaken over four weeks in twenty-one of Brazzaville's municipal markets. The results showed that women were most involved

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in this trade (52 %). Market traders' monthly income was estimated at 210,428 ± 49,128 FCFA (US $ 420 ± 98). On average, the bushmeat traders were 39 ± 10 years old and 69 % of them attended the two levels of secondary education. During four weeks, 3,711 animal carcasses were recorded in the twenty-one surveyed markets, representing a biomass of almost 4290.47 kg. Overall, thirty-five animal species were identified, including nine the hunting of which was prohibited. Mammals constituted 93.8 % of a total number of hunted animals, with three dominant orders as the artiodactyls (49.2 %), the rodents (22.6 %) and the primates (17.7 %), of which *Cephalophus*, *Potamochoerus*, *Atherurus* and *Cercopithecus* were most represented.

Presently, there is no indication that the quantities of meat offered on Brazzaville markets are being reduced because hunting areas extend always further, often to the detriment of protected areas, and the fact that the business of bushmeat marketing continues to grow suggests overexploitation is occurring.

Activities promoting game farming and breeding of domestic species in the Brazzaville suburbs could be relevant hunting methods and implementation of legal setting and regulations concerning bushmeat trade.

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Agricultural Biodiversity: a Crucial Asset for Food and Nutrition Security

by

Emile FRISON*

SUMMARY.** — While significant progress has been made in total food production over the last fifty years, we still have close to one billion people suffering from hunger and two billion more suffering from malnutrition. Today, more people die from non-communicable diseases related to an imbalanced diet which is energy rich but nutrient poor than from communicable diseases or from hunger. In addition, the greater frequency and intensity of extreme weather events and greater unpredictability of rainfall patterns observed today are increasing the risks, particularly for poor smallholder farmers.

Greater use of agricultural biodiversity, both different species and intraspecific diversity, can play a significant role in achieving multiple benefits. Greater diversity in the production systems can provide for more diverse and healthier diets while at the same time increasing the resilience of the production system, providing better ecosystem services and more diversified sources of income. Examples of successful deployment of diversity in smallholder production systems along with research under way to tackle world issues such as climate change, poverty and malnutrition will be presented.

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** PowerPoint presentation: cf. CD-ROM.

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Food Production and Plant Genetic Engineering in Developing Countries

by

Nathalie VERBRUGGEN*

KEYWORDS. — GMO; Biotech Crop.

SUMMARY. — The area of genetically modified or transgenic plants — *i.e.* issued from a genetic transformation in laboratory —, now called "biotech plants" or "biotech crops", is growing rapidly worldwide. Almost two decades ago, after the first marketing of a transgenic plant, this area has reached more than 170 million hectares in 2012. Major biotech crops are soybean, maize, cotton and canola. While the first transgenic plant (published thirty years ago) was European (Belgian), biotech crops are mainly grown in America (North and South), India and China. For the first time since the introduction of biotech crops, there is a larger area of biotech crops grown in developing countries than in industrialized countries. In this paper, I shall present the evolution of what some call the third agricultural revolution. New biotech crops likely to be commercialized in developing countries will be sketched. Traits include insect resistance, virus resistance, drought tolerance, biofortification, yield enhancement, etc. ... also in orphan crops. Likely implications of these new biotech crops on food security and nutrition in developing countries will be addressed.

Presentation of the Paper

The subject will be treated in two parts: first, plant genetic engineering and the history and development of biotech crops will be introduced. The second part will focus on biotech crops already marketed or to be commercialized in a near future in developing countries, in particular in Africa.

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Since when do We modify the Genomes of Plants?

Genetically modified plants, also called transgenic plants, belong to the family of so-called "genetically modified organisms" (GMO). GMOs have a legal definition in Europe: a GMO is an "organism, with the exception of human beings, in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination" (Directive 2001/18/EC, Article 2). It means that genetically modified plants are obtained in laboratory by genetic transformation also called transgenesis. Today, genetically modified crops are named biotech crops. Since when do we modify the genomes of plants?

Plant genome naturally evolves over time. Since he became a farmer, man has changed and shaped plant genomes for his own use. Maize, for example, is a human creation. Man has accumulated several mutations resulting in the production of a larger ear with grains remaining attached to the ear. This feature is not favourable for maize because obviously it makes it unable to survive in a natural ecosystem. When the corn falls to the ground, all the seeds germinate at the same place. The ancestors of our crops have not evolved to be eaten by Man. Those of the tomato and potato have appeared in the Andes; the first samples imported into Europe in the early eighteenth century were inedible. It took all the ingenuity of farmers and breeders to improve and make them fit for culture and consumption. Our ancestors, while inventing agriculture and livestock, have profoundly changed their environment. Most of the plants and animals we eat are therefore not natural but the product of a long, continuous, discrete and time-consuming process of improvement.

Globally, all our crops can be considered as genetically modified from a scientific point of view but not considering the legal definition, which only takes into account genetic modification by genetic transformation.

Since when do We do Plant Genetic Engineering?

Long before Man existed, the bacterium *Agrobacterium tumefaciens* transforms plant cell to cause crown gall. Historically the study of this disease, which is a kind of tumour, enables to identify the first and unique natural mechanism of gene transfer to plants. The Belgian team of Marc Van Montagu and Jeff Schell at the Ghent University played a pioneering role in this scientific discovery. *Agrobacterium tumefaciens* contains a large-size plasmid, Ti for "tumor inducing". After infection, a specific fragment of the Ti plasmid, called

T-DNA ("transferred DNA"), which contains the genes causing the plant tumour, is inserted into the chromosomal DNA of host plant cell. The Ghent University team used *Agrobacterium tumefaciens*, from which they removed the genes causing the crown gall disease on the T-DNA, and which they replaced by genes they had chosen to be expressed by the plant. The first published transgenic plant is Belgian — it dates from 1983 and was published in *Nature* (HERRERA-ESTRELLA *et al.* 1983). Today, for "recalcitrant plant species" to *Agrobacterium tumefaciens,* other transformation methods are used.

This technology, the ability to genetically transform plants, now thirty years old, has revolutionized basic research in plant biology, has led to a better understanding of the processes of disease resistance, photosynthesis, growth, etc. and has also broadened the field of possibilities for crop improvements. The first (1994) commercially-grown genetically engineered food was a genetically modified tomato (Flavr Savr). Biotech crops we are still cultivating today were commercialized in 1996.

In 2013, Marc Van Montagu and two American scientists received the World Food Prize for their individual, independent breakthroughs as founders of modern green biotechnology and their contribution.

Where are Biotech Crops cultivated?

While Europe has been a pioneer in this technology, we see today that it is developing everywhere outside Europe. In 2012, twenty-eight countries grew biotech crops. In these countries more than half of the world's population is living. The six largest biotech crops growing countries (representing 90 % of the total biotech crop area) are the USA, Brazil, Argentina, Canada, India and China.

Since 1994 — when the first marketing of biotech crops was launched —, cultivated areas have continued to increase, reaching more than 170 million hectares, or more than 10 % of the world's cultivated area (1.5 billion hectares), in 2012. Developing countries have now equalled and even exceeded the surfaces of the industrialized countries.

Which Biotech Crops are cultivated Today?

On most surfaces only four species of biotech varieties are cultivated: soy bean, maize, cotton and canola. Biotech surfaces represent 81 %, 35 %, 81 % and

30 % of the total surfaces grown with soy bean, maize, cotton and canola respectively. The rest of the surfaces is thus cultivated with non-biotech varieties.

Only two different genetically engineered traits are among the most planted biotech crops: herbicide tolerance (HT) and insect resistance.

Herbicide tolerance is a trait that helps to manage weeds. Plants are resistant to total herbicides that are rapidly degraded in the soil like Roundup or Basta (both total herbicides kill major weeds). Biotech crops are equipped with a system to degrade or with a resistant enzyme to the total herbicide. Insect resistance can be achieved by introducing genes of *Bacillus thurigiensis* (Bt), a soil sporulating bacterium. Its spores are widely used in organic farming as natural insecticides. Toxins contained in the spores selectively kill certain types of insects and are reported not to affect other living organisms. Genetic engineering has produced Bt crops which are modified to synthetize specific Bt proteins to protect against specific pests.

The constant request to increase yield mainly explains the choice of the genetic traits largely introduced into biotech crops. One third of the potential agricultural yield is lost worldwide because of weeds, pests and diseases. To reduce agricultural losses, chemicals that have an impact on human health and the environment are used. There is a need for sustainable but efficient agriculture able to feed 10 billions of people in the near future. Given the cost of research, but also of marketing (more than 10 million euro for a biotech crop that is nutritionally equivalent to a conventional crop, and more than 20 million euro for a nutritional non-equivalent crop), the biotech crop must be profitable, which is the case by addressing important causes of yield losses.

In 2013, researchers from the European Commission published a meta-analysis of the economic and agronomic impacts of biotech crops. From this analysis it appears that "... GM crops perform better than their conventional counterparts in agronomic and economic (gross margin) terms. Regarding countries' level of development, GM crops tend to perform better in developing countries than in developed countries, with Bt cotton being the most profitable crop grown" (AREAL *et al.* 2013).

Focus on Developing Countries

Developing countries are usually defined by a gross domestic product (GDP) below $12,475. More than half of the biotech crop surfaces are located in developing countries. The emerging countries must be distinguished among developing countries by their high rate of GDP growth, relatively high level of industrialization and export of industrial products, strong open-

ing to the outside and a market rate expanding inside. Examples of emerging countries are Brazil, India and China, which represent about 40 % of the world population and 30 % of the total biotech surfaces.

In Africa, only a few countries grew biotech plants in 2012: South Africa, Burkina Faso, Egypt and Sudan. There are field trials (but not commercial growth) of biotech crops in Nigeria and in Uganda. The reasons for the lack of development include opposition to this technology (and we can say that Europe plays a significant role) and/or the lack of regulation of biosafety. Mali, Kenya and Ghana have recently adopted biosafety laws. In the Democratic Republic of Congo (which is the subject of the symposium) there is neither (official) biotech crop grown surface nor GMO biosafety regulation.

Before going on, I want to emphasize that "GMOs are not the only or even the main solution to current problems in Africa and, in addition to technology, it is essential to invest broadly in infrastructure, including human resources, scientific facilities and more general infrastructure for social and economic development" (EASAC 2013).

What are the Marketed Food Biotech Crops in Africa?

Bt maize is approved for commercial production in South Africa since 1998/99 and in Egypt since 2008. The South African smallholder GM maize experience has been — to date and internationally — the only example of a subsistence crop produced by smallholder resource-poor farmers using GM seed (GOUSE 2012). HT soybean is also largely adopted in South Africa. Bt cotton, which was developed to resist to the African bollworm (*Helicoverpa armigera*), is cultivated in South Africa, Burkina Faso and Sudan.

Globally GM crops performed best in developing countries (compared to developed countries), probably due to the lack of efficient pest management practices and the expense of pesticides (AREAL *et al.* 2013; BROOKES & BARFOOT 2009, 2012; CARPENTER 2010, 2011; FINGER *et al.* 2011).

I will now present projects of biotech food in developing countries (with a particular attention to Africa) that address local needs.

Golden Rice

Genetic engineering does not only serve to improve agricultural practices, but allows for a multitude of applications in human health or industry.

Nutritional deficiencies, such as vitamin A and iron or zinc, increase morbidity and mortality and particularly affect children.

Vitamin A deficiency can lead to blindness and other diseases affecting vision and eye disorders (xerophtalmia keratomalacia), decreases immunity favouring respiratory diseases and diarrhea. For some crops, like sweet potato, there are pro-vitamin A-poor white varieties, and pro-vitamin A-rich varieties with orange flesh. In this case, what needs to be done is to introduce the A-rich varieties to people used to the white-fleshed varieties. Unfortunately, for rice, there are no varieties rich in pro-vitamin A in the grain endosperm. It is estimated that 70 % of the pre-scholar children may suffer from vitamin deficiency in Southeast Asia. A daily ration of 150 g of cooked rice may provide sufficient pro-vitamin A (this figure is controversial because it depends on the health status of the population). Vitamin A (clinical level) is also largely present in Africa (West *et al.* 2010).

The first variety of pro-vitamin A enriched rice, called "Golden Rice", easily recognizable by its yellow to orange colour, was published by Ingo Potrykus and his colleagues in 2000 (Ye *et al.* 2000). Golden Rice has been improved since then to accumulate even more pro-vitamin A (B-carotene), see http://www.goldenrice.org/

From the beginning, Golden Rice has been conceived as a public-good project. Commercialization is foreseen royalty-free in the Philippines (in 2014), China, Bangladesh, India, Indonesia, Vietnam. Golden Rice represents a public-private cooperative project, with funding from the Rockefeller Foundation, the Bill & Melinda Gates Foundation (Grand Challenges in Global Health Initiative), the U.S. Agency for International Development, the Philippine Department of Agriculture, HarvestPlus, the European Commission, Swiss Federal Funding & the Syngenta Foundation.

Development of Golden Rice in Africa is possible, with the transfer of the new trait into local varieties. However, the difficulties of commercialization due to GMO-regulation are not to be neglected.

African Biofortified Sorghum

Sorgum is Africa's second most important cereal after maize in terms of tonnage. The continent produces about 20 million tons of sorghum per annum, about one third of the world production. The African Biofortified Sorghum (ABS, http://biosorghum.org) is a project aiming at developing a transgenic sorghum that contains increased levels of essen-

tial nutrients, especially lysine, Vitamin A, iron and zinc. The project is supported by the Bill and Melinda Gates Foundation and the technology was donated by Pioneer. A significant portion of the ABS research is taking place in South Africa. There have been six successful sets of field trials conducted in the USA, trials in controlled conditions (greenhouses) in South Africa and Kenya and there are pending field trials in Kenya and Nigeria.

Global Cassava Partnership for the 21st Century

Cassava ranks sixth as source of carbohydrates globally. Cassava is used for the production of starch, flour, biofuel and beer. It is a vital crop which is resilient to climate change and tolerates poor soils. Two hundred and fifty million sub-Saharan Africans and six hundred million persons globally rely on cassava as their major source of calories. Nigeria is the largest cassava producer in the world. Global Cassava Partnership for the 21st Century (GCP21, http://ciat.cgiar.org/gcp21) is a project aiming at developing cassava varieties resistant to Cassava Mosaic and Brown Streak virus (CMV, CBSV; these viruses are responsible for one third of the yield loss in Africa), and also cassava biofortified in pro-vitamin A and iron.

CBSD resistance has not been found in cassava genotypes traditionally grown by farmers. Exploitation of the plant immune system against viruses by expression of hairpin RNA homologous to viral sequences has proven effective to generate virus-resistant crops including cassava. This approach has been successful to create CDSD resistant cassava in the laboratory, which awaits field test evaluation (VANDERSCHUREN *et al.* 2012). Field assays are conducted in Tanzania, Kenya, Nigeria and Uganda. The project is supported by a public/private consortium: Rockefeller Foundation, U.S. Agency for International Development, the Bill & Melinda Gates Foundation, the Howard G. Buffett Foundation, the Monsanto Fund, SNP, the U.S. Department of Energy and the Roche Company.

Maruca-resistant Cowpea

The Maruca pod borer is an insect pest that preys upon cowpea plants in many African countries. These insects are a major problem in cowpea production in West Africa, leading to severe yield loss.

Maruca-resistant transgenic Bt cowpeas have been engineered to produce the Cry1Ab toxin (insecticide) originated from *Bacillus thurigiensis*. Authorization for field trials of Maruca resistant cowpeas is pending in Nigeria, Burkina Faso and Ghana. The developers expect to have the first Maruca-resistant cowpea seed available for farmers in 2017.

The project is conducted by a public-private sector consortium under a royalty-free licence. The African Agricultural Technology Foundation (AATF) manages the project and collaborates with the Network for the Genetic Improvement of Cowpea for Africa (NGICA), the Commonwealth Scientific and Industrial Research Organization (CSIRO) Australia, the Institute for Agricultural Research (IAR) Zaria, Nigeria, the Savanna Agricultural Research Institute of the Council for Scientific and Industrial Research (CSIR-SARI) Tamale, Ghana, the Agricultural Research Institute of Burkina Faso (INERA), the International Institute of Tropical Agriculture (IITA), the Kirkhouse Trust, the Programme for Biosafety Systems (PBS) and Monsanto. Financial support is given by the Rockefeller Foundation and the U.S. Agency for International Development.

Drought-tolerant Maize

Seventy-five percent of the world's most severe droughts over the past ten years have occurred in Africa and maize is the most widely grown staple crop in Africa. WEMA is the acronym of Water Efficient Maize for Africa (http://wema.aatf-africa.org/about-wema-project), a project developing drought-tolerant and insect-protected African maize varieties for sub-Saharan Africa, with a focus on Kenya, Mozambique, South Africa, Tanzania and Uganda.

In WEMA the maize varieties will be developed using conventional breeding, advanced breeding techniques or marker-assisted breeding and transgenic breeding, sometimes referred to as genetic modification. The goal here is not to improve the productivity strict sense, but to achieve the same performance using less water or limiting losses during peak heat.

Compared to local varieties grown in the five partner African countries with very low yields (around 1 to 1.5 tons per hectare), the maize tolerant to water stress is expected to improve the production with 20 to 35 % over the next ten years, the equivalent of two million tons of additional food.

The drought-tolerant maize will be made available for farmers facing water shortages. First in the United States, then in Africa in 2017, thanks to

the WEMA International Programme, which aims at introducing free in the relevant varieties of corn used by local farmers to feed genes. The benefits and safety of maize varieties will be assessed by national authorities in accordance with regulatory requirements in Kenya, Mozambique, South Africa, Tanzania and Uganda.

This project brings together private companies (Monsanto, Pioneer), the Howard G. Buffett and USAID Foundations and especially the Farm Bill and Melinda Gates Foundation, the National Agricultural Research Institutes in Kenya, Mozambique, South Africa, Tanzania and Uganda, the International Maize and Wheat Improvement Center (CIMMYT).

Possible Consequences of Biotech Crops for Food Security in Africa?

There is a widespread opposition to biotech crops, not based on scientific but rather on ethical, philosophical or political arguments. The dominance of a highly concentrated private sector has raised concerns. A worry is that patenting and intellectual property rights will lead to monopolization of knowledge, restricted access to germplasm, and increasing marginalization of the majority of the world's population. Those concerns cannot be ignored.

The "need to feed the world", with predicted nine billion people by 2050, is not a trivial matter, particularly in developing countries, where malnourishment and starvation are a pressing concern.

There is no doubt that biotech crops are one of the possible tools to improve yield, decrease use of toxic chemicals and increase nutritive quality at a time of increasing pressures from climate change, social and economic inequity and instability. Increasing yields in an environmentally sustainable manner is the best way to increase sustainability. However, "it is important to keep in mind that malnutrition is to a great extent rooted in political, economic and cultural issues that will not be solved by a technical fix" (from http://www.goldenrice.org/).

REFERENCES

AREAL, F. J., RIESGO, L. & RODRIGUEZ-CEREZO, E. 2013. Economic and agronomic impact of commercialized GM crops: a meta-analysis. — *Journal of Agricultural Science*, **151**: 7-33.

BROOKES, G. & BARFOOT, P. 2006. Global impact of biotech crops: socio-economic and environmental effects in the first ten years of commercial use. — *AgBioForum*, **9**: 139-151.

BROOKES, G. & BARFOOT, P. 2012. GM crops: global socio-economic and environmental impacts. — PG Economics. http://www.pgeconomics.co.uk/page/33/global-impact-2012

CARPENTER, J. E. 2010. Peer-reviewed surveys indicate positive impact of commercialized GM crops. — *Nature Biotechnology*, **28**: 319-321.

CARPENTER, J. E. 2011. Impact of GM crops on biodiversity. — *GM Crops*, **2**: 7-23.

European Academies Science Advisory Council (EASAC) 2013. Planting the future: opportunities and challenges for using crop genetic improvement technologies for sustainable agriculture. — Policy report 21, ISBN: 978-3-8047-3181-3.

FINGER, R., EL BENNI, N., KAPHENGST, T. *et al.* 2011. A meta-analysis on farm-level costs and benefits of GM crops. — *Sustainability*, **3**: 743-762.

GOUSE, M. 2012. GM maize as subsistence crop: The South African smallholder experience. — *AgBioForum*, **15**: 163-174.

HERRERA-ESTRELLA, L., DEPICKER, A., VAN MONTAGU, M. & SCHELL, J. 1983. Expression of chimaeric genes transferred into plant cells using a Ti-plasmid-derived vector. — *Nature*, **303**: 209-213.

NAVARRO, M. J., NATIVIDAD-TOME, K. G. & GIMUTAO, K. A. 2013. From Monologue to Stakeholder Engagement: The Evolution of Biotech Communication. — ISAAA Briefs, 45, ISBN: 978-1-892456-54-0.

VANDERSCHUREN, H., MORENO, I., ANJANAPPA, R. B., ZAINUDDIN, I. M. & GRUISSEM, W. 2012. Exploiting the combination of natural and genetically engineered resistance to Cassava mosaic and Cassava brown streak viruses impacting Cassava production in Africa. — PloS ONE, **7**: e45277.

WEST, K. P. Jr., KLEMM, R. D. W. & SOMMER, A. 2010. Vitamin A saves lives. Sound science, sound policy. — *World Nutrition*, **1**: 211-219.

YE, X., Al-BABILI, S., KLOTI, A., ZHANG, J., LUCCA, P., BEYER, P. & POTRYKUS, I. 2000. Engineering the Provitamin A (β-Carotene) Biosynthetic Pathway into (Carotenoid-Free) Rice Endosperm. — *Science*, **287**: 303-305

Agricultural Practices

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Production of Animal Protein in the Congo Basin, a Challenge for the Future of People and Wildlife

by

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SUMMARY. — Protein needs are considerable in the Congo Basin, a vast territory dominated by forest and inhabited by tens of millions of people. Whereas over 85 % of the DRC's population of the Basin lives in the forest, the situation is different in other countries, where the majority is urban (Cameroon, the Central African Republic, Congo and Gabon). This paper presents several achievements of the Centre for Tropical Agriculture and Veterinary Medicine in Kinshasa (CAVTK), which, since 2001, aims at conducting pilot projects in animal husbandry and agriculture, highlighting the skills of the Belgian universities, breeders and entrepreneurs. Different production runs are presented, going from the cattle ranching operations in Katanga, poultry breeding in Bas-Congo, through rabbits in Butembo, mini-livestock and insects.

Introduction

The Congo Basin is a vast territory covering Angola, Cameroon, the Central African Republic (CAR), the Democratic Republic of the Congo (DRC), the Republic of Congo, Burundi, Rwanda, Tanzania and Zambia, dominated by forest and inhabited by tens of millions of people.

Whereas over 85 % of the DRC's population of the Basin lives in the forest, the situation is different in other countries, where the majority is urban (Cameroon, the Central African Republic, Congo and Gabon).

Depending on the vegetation and the climate, forests or commercial plantations, where rainfall can go up to 4,000 mm/year, and livestock and subsistence farming, with rainfall below 750 mm/year, are observed.

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According to TOLLENS (2010), except for the CAR and Equatorial Guinea, the agricultural sector in the Congo Basin countries has a dualistic character: large groups of smallholder family farms *vs.* larger commercial plantations (Cameroon, Gabon and the DRC).

Protein needs are considerable in the Congo Basin. According to FA *et al.* (2003), non-bushmeat protein (mainly crops or animal-derived products including meat, seafood and fish) derives from domestic agriculture and from imports that vary from 6 % of the total supply in the DRC to 55 % in the Congo.

The consumption of wildlife meat constitutes an important source of animal proteins for the rural and urban population in Congo and, in some regions, becomes a component of the subsistence diet. In his remarkable book on edible wild products in the Democratic Republic of the Congo, MALAISSE (1997) describes the animal species concerned in the context of animal protein: large mammals, rodents, birds, fish, reptiles, caterpillars, termites and other insects.

For a better understanding of this protein contribution, a quantitative survey on the consumption of bushmeat was undertaken by Mbete *et al.* in Brazzaville during 2006, among about 1,050 urban households (MBETE *et al.* 2011b).

The survey's objective was to draw the profile of the bushmeat consumers and their motivations, to evaluate their consumption, to identify the most consumed mammals and to collect their perception of the microbiological quality of bushmeat as well as their perception of game breeding.

The results of MBETE *et al.* (2011b) showed that the consumption of bushmeat concerned 88.3 % of the households surveyed. The urban consumer is generally an educated adult whose average age is 44.4 ± 12.3. He has a permanent employment and has an average income of 98,334 ± 84,306 CFA (150.1 ± 128.7 €). The average number of persons per household is 5.7 ± 3.2. More than 80.6 % of the surveyed persons expressed a concern regarding food safety, more particularly targeting the threat of Ebola, and wished this concern to be handled by public health services.

Bushmeat is an attractive food for its good organoleptic qualities, but this appreciation has equally been influenced by social habits. The games are mostly mammals, belonging to three main genders: the artiodactyls (49.3 %), the rodents (31.5 %) and the primates (14.0 %). The increasing price of bushmeat, in an increasing impoverished population context, along with zoonotic diseases, such as Ebola hemorrhagic fever (mostly for primate consumers), have appeared as two main factors limiting the consumption.

With a daily bushmeat consumption per person about 180 g in Gabon, 50 g in Congo, 30 g in the CAR and 20 g in the DRC and Cameroon, whatever the location of the populations, biodiversity will be inevitably put in danger given the demographic growth in these countries. If agricultural alternatives fail to be developed, this loss of natural resource will be a threat to local populations themselves. The central part of the Basin would be more affected by this phenomenon.

A similar survey undertaken by DELVINGT *et al.* (2002) in villages around the Dja reserve in Cameroon, the Odzala National Park in Congo and the Ngotto forest in the Central African Republic revealed that the average bushmeat consumption varies between 80 and 160 g/person/day.

The fauna's overexploitation in the Congo Basin appears as a crucial problem (VERMEULEN & DOUCET 2006). Therefore, as suggested by MBETE (2012), strategies aiming at guiding consumers towards other protein sources, or else, undertaking game farming or game ranching activities, must be promoted. It is also necessary to carry out awareness-raising campaigns among the bushmeat network actors, through participatory approaches in natural resources management.

There are several solutions intended to maintain the supply of bushmeat: game farming, hunting control, market control, actions on prices, consumer education and livestock development.

Cattle, Sheep and Goats (tabs. 1, 2)

Cattle in the Congo Basin is essentially in the hands of large companies engaged in ranching operations over large surfaces. According to MAMMERICKX (1986), it is in 1886 that imported cattle from Angola and the island of Madeira arrived on the island of Mateba (estuary of the Congo river). This was actually the start of the first cattle breeding operation in the DRC leading to several thousands of heads of cattle in 1900 known as Mateba island cattle.

Later, given the presence of the tsetse fly, responsible for the transmission of trypanosomosis, imports of West African cattle led to the multiplication of N'Dama breed (fig. 1) in Bas-Congo especially by the JVL, a company that is currently part of the Orgaman group which also has operations in Bandudundu.

Later, cattle breeding was practiced in several regions of the DRC, particularly in Katanga (Grelco, Pastorale, Marungu, Kundelungu). Currently, the largest company of the Group Forrest International (GFI), the *Grands*

Elevages de Katongola (Grelka), has 35,000 head of cattle of the Grelka breed of Afrikander origin and improved recently (2008) by Bonsmara cattle (fig. 2), imported from South Africa. An experimental cross with Belgian Blue cattle was launched in 2008. Grelka operates in altitude on the Biano plateau and produces castrated bulls, sold at four years old.

Cattle breeding is also observed in Gabon, where the company SIAT continues the cattle ranching of the N'dama, Senepol crosses and Zebu Goudali imported from Cameroon.

In Cameroon, cattle is mainly located in the North (> 75 %) and in the high-altitude pastures of the Adamaoua plateau (15 %).

For TOLLENS (2010), the only livestock encountered in the humid rainforest are sheep and goats. The author discusses the resilience and the adaptation of sheep and goats, the preferred livestock in the rainforest.

Table 1

Production of meat, milk and eggs, 1995-2007, Congo Basin, thousand tons

	Meat		**Milk**		**Eggs**	
	1995	2007	1995	2007	1995	2007
Cameroon	180	221	183	189	13	13
CAR	89	118	50	65	1	1.2
DRC	212	157	7	5	9	6
Eq. Guinea	-	-	-	-	-	-
Gabon	28	32	1	2	2	2
Rep. of Congo	22	31	1	1	1	1

Source: The State of Food and Agriculture 2009, FAO, Rome, table A1, pp. 128-129. From TOLLENS (2010).

Table 2

Production of pigs, poultry, cattle and sheep, 1995-2007, Congo Basin, thousand tons

	Pigs		**Poultry**		**Cattle**		**Sheep**	
	1995	2007	1995	2007	1995	2007	1995	2007
Cameroon	12	16	21	30	73	92	28	21
CAR	10	13	3	4	48	74	8	13
DRC	28	24	13	11	16	13	23	21
Eq. Guinea	-	-	-	-	-	-	-	-
Gabon	2	3	3	4	1	1	1	1
Rep. of Congo	2	2	6	5	1	2	1	1

Source: The State of Food and Agriculture 2009, FAO, Rome, table A2, pp. 133-134. From TOLLENS (2010).

Fig. 1. — N'Dama Cattle – *Compagnie JVL*, Kollo, Bas Congo, DRC (Picture: P. Leroy, 2010).

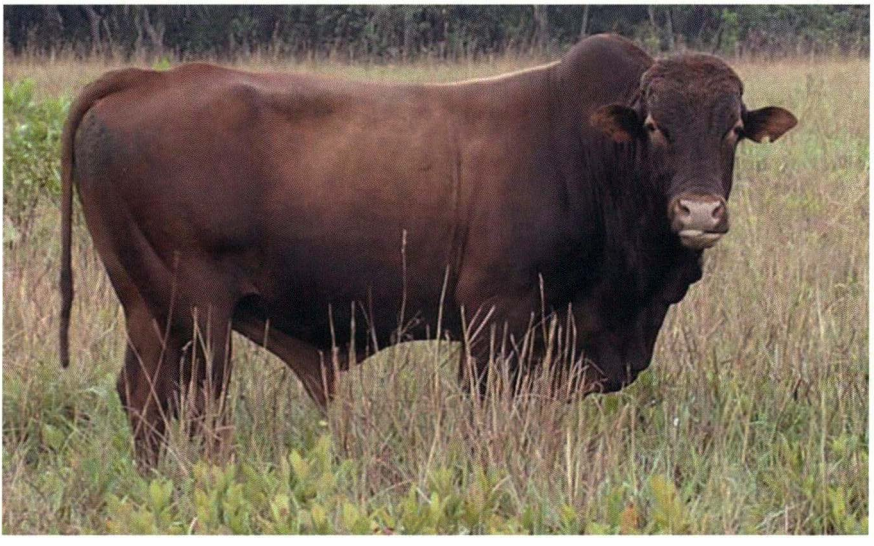

Fig. 2. — Bonsmara Cattle – Grelka (Group Forrest International), Biano, Katanga, DRC (Picture: P. Leroy, 2008).

Alternatives to Poaching

Minilivestock

As indicated by Hardouin (2005), the concept of minilivestock is accepted as a normal tool and component for rural development in the tropics. Knowledge in the minilivestock sector is organized by BEDIM, an international non-profit organization located in Gembloux and dedicated to the collection, processing and dissemination of information on animal species under the minifarming and the use of their products.

In the context of minilivestock, the grass cutter (*Thryonomys swinderianus*), the African brush-tailed porcupine (*Atherurus africanus*) and the cricetomys (tab. 3) have been studied in several countries of the Congo Basin.

The African brush-tailed porcupine (*Atherurus africanus*) is the wild rodent preferred by bushmeat consumers of the Congo Basin, especially in Gabon (Edderai & Houben 2002). It thus constitutes a source of proteins for urban dwellers and a source of considerable income for actors involved in this value chain. Indeed, the insatiable demand of the urban centres encourages the inhabitants of forest to engage in the poaching and marketing of this species. After having shown the general characteristics of the species, Mondi Ikobo *et al.* (2013) review the current data on its reproduction, nutrition and diseases. The aspects related to the consumption and the marketing are also discussed.

Table 3
Several characteristics of the different species were given by Jori (2001)

	Grass cutter	***Atherurus***	**Cricetomys**
Adult weight	3	2.8	1.3
Gestation length (d)	150	120	30
Birth weight (g)	120	135	20
Litter size	4	1	3.5
Litters / year	1.8	2.3	6
Slaughter weight (kg)	3.5	3	1.5
Killing out (%)	65	6.7	52
Sexual maturity (kg)	1.5	2	0.6

Small-scale Farming

The intention of minilivestock and small-scale farming is not only to meet the needs for animal protein, but it also shows advantages in the socio-

economic characteristics of its production. Thus, it has a particular role to play in poverty alleviation. Indeed, they constitute a sustainable alternative for meat production, for several reasons. First, they require little investment and are, for this reason, low-risk activities while generating steady income. The steady income they provide is especially valuable in contexts where financial services are lacking and where social and own economic pressures to spend the money available are high. Most of these minilivestock species require less space than larger species and are thus accessible to poor households, including those that do not own any land. For the same reason, it constitutes a viable urban or periurban activity. In addition, technical management and monitoring of these types of livestock are accessible to most stakeholders. As a result, a traditional gender-bias is observed in most cultures, explaining the major involvement of women in such activities. This is an opportunity to use the promotion of minilivestock in the empowerment of women inside communities. Lastly, backyard poultry, sheep, goats, pigs, rodents (grass cutter), lagomorphs (rabbits), insects, snails and aquaculture are generally prone to enter short-supply chains that ensure a maximal part of the value-added to be kept at the level of the farmer.

In the survey by MOULA *et al.* (2012c) among poultry-keeping households in Bas-Congo (DRC), besides poultry, the species raised were goat, guinea pig, sheep, duck, rabbit and pigeon (tab. 4). Those households also cultivated the following crops: cassava (pondu, saka-saka) (100 %); vegetables (tomato, onion, pepper and eggplant: 100 %); corn (84.4 %); peanuts (81.8 %); beans (57.1 %); soybeans (54.5 %); sweet potato (37.7 %); yams (31.2 %); sesame (26.0 %); millet (13.0 %); okra (10.4 %) and coffee (5.2 %).

Table 4
Relative livestock distribution (%) by species in the Bas-Congo (DRC)
(MOULA *et al.* 2012c)

Species	Farm (%)	Number of animals			
		Mean	Median	Maximum	Minimum
Goat	44.20	3.47 ± 3.19	3	16	1
Guinea pig	20.80	8.37 ± 6.36	7	23	2
Pig	13.00	4.50 ± 2.69	2	12	1
Sheep	7.79	3.83 ± 2.14	3	8	3
Duck	7.79	8.67 ± 3.82	9	11	5
Rabbit	7.79	3.83 ± 2.14	3	8	3
Pigeon	2.60	8.00 ± 1.41	8	9	7

BACKYARD POULTRY

Indigenous chicken breeds contribute significantly to the world production of meat and eggs (MOULA 2012 a, b). They are mainly raised as backyard poultry, and represent 80 % of the world poultry population. However, the majority of these breeds has not been recorded and studied (BESBES 2009). About 40 % of the poultry breeds have an unknown risk status. Hence, considerable efforts are necessary to evaluate them (RISCHKOWSKY & PILLING 2008).

Backyard poultry refers to low-input production systems, with a financial or social role rather than being a true income-generating activity. Poultry is then often part of a diversified livestock portfolio, as highlighted above. Women or children are often in charge of the management of the flock, as highlighted by MOULA *et al.* (2012c) in their survey in Bas-Congo, where women were in charge of poultry breeding in 42.9 % of the interviewed households. In the same survey, the interviewed farmers stated various rationales for keeping poultry. The main reasons are meat (45.5 %) and tradition (59.7 %). The reasons to prefer the indigenous breed were the organoleptic quality of chicken meat and eggs (15.6 %), the toughness and resilience (53.3 %) and the ease of breeding (75.3 %).

Still according to MOULA *et al.* (2012c), concerning feed and feeding systems for chickens in Bas-Congo, 77 % of the farmers provided supplementary feeding to their chickens, as *e.g.* kitchen leftovers (65.5%) or crop residues (94.2 %); 10.4 % of the chicken breeders used a nutrition formula (50 % corn, 30 % soya and 20 % manioc (10 % leaves and 10 % spuds)) that had been suggested by a locally active NGO. Twenty-three percent of the farmers do not feed them and the animals collect their food in their environment (insects, worms, grasshoppers, larvae, grass, crops, ...). The majority of backyard-chicken keepers provided water to the birds (79.2 %). The mainly cited constraints on the productivity of family-based poultry are predators (93.5 %), diseases (80.5 %), expensive chicken feed (22.1 %) and theft (26 %).

Households in the Congo Basin generally practice the farming of indigenous chicken as a secondary activity. It is part of a wider livelihood strategy, with a diversification aiming at risk management. Therefore, the contribution of this activity to food security is already effective and crucial. Basing further improvement of food security, in terms of quantity and quality of the diet, on that production could be achieved in two ways. One would fully accept the status of side activity of poultry keeping and maintain the improvement actions in the strict framework of low-input systems. Such actions could then apply to all chicken-keeping households. Vaccination is an example of such

actions, as recently implemented by the Centre for Tropical Agriculture and Veterinary Medicine in Kinshasa (CAVTK) (fig. 3) in Bas-Congo. Another way might be of interest to only part of the presently involved actors. Indeed, some actors might engage in some professionalization aiming at income generation through the sale of poultry products. Particularly women would then organize themselves to improve their production systems and gain access to information, inputs, financial services and outlet markets.

Fig. 3. — Ardennaise poultry breed in Kinshasa, CAVTK project (Picture: P. Leroy, 2008).

Rabbits

Rabbit breeding has several advantages. First, there is an overall cultural acceptance of its consumption (apart from the Adventist religion). Secondly, the investment and labour in rabbit breeding are relatively inexpensive. Furthermore, it can be run on small surfaces, allowing for its practice in (sub-) urban settings. Finally, rabbits are good converters of crop residues, weeds, waste of fruits and vegetables.

In Butembo, in the East of the DRC, rabbit breeding was chosen as part of a strategy for the development of urban agriculture to improve food security in a context of military conflict and presence of a large refugee population (Vumilia Kasuki 2012-2013).

Nevertheless, rabbits are known for their susceptibility to poor hygiene, heat and well-identified infectious diseases. Hence, the training of the new practionners is an important step to ensure the sustainability of such actions. The monitoring by veterinarians and a close technical assistance to newcomers are also essential.

Guinea Pigs

The guinea pig (*Cavia porcellus*) is a small herbivorous rodent originating from the central highlands of the Andes, where they were domesticated for their meat and their population is estimated at 36 million (Ngou Ngoupayou *et al.* 1995).

As indicated by Hardouin *et al.* (1991) and Bindelle *et al.* (2007), low productivity of the guinea pig in tropical Africa is essentially due to a lack of management.

According to Bindelle *et al.* (2007), in Africa only limited research has been carried out in Cameroon to improve the traditional rearing and feeding systems.

In *Troupeaux et Cultures des Tropiques*, the thematic publication of the Centre for Tropical Agriculture and Veterinary Medicine in Kinshasa (CAVTK), Nkidiaka (2004) studied the urban and periurban practices in Kinshasa, where guinea pigs are raised by 7 % of the people keeping farm animals at home, representing around 30 % of the families in the periurban area.

In the same thematic publication of the CAVTK, Bindelle & Picron (2012) described the main reproduction characteristics: puberty in male (3.5 months), female (1 month), estrus cycle (15 days), gestation length (2 months), reproduction interval (65-80 days), gestation length (2 months), weaning (21 days), litter size (3), age at adult weight (5 months), culling after 6 litters, life time (5 years).

The productivity is mainly influenced by the reproduction cycle length, partly influenced by the farmer, and by the management.

In Cameroon, the live weight of guinea pigs reaches around 350 g with a dressing out percentage of 70 % (Niba *et al.* 2004). Higher values were obtained in the Andes and also in Kivu (DRC).

Regarding nutrition of the guinea pig, a combination of *Panicum maximum* with *Desmodium intortum*, *Euphorbia heterophylla* or *Amaranthus hybridus* was suggested to the farmers in a recent study conducted by Bindelle *et al.* (2007).

In a huge selection experiment involving 202 sires, 718 dams and 3,192 progeny QUIJANDRIA *et al.* (1983) found a value for heritability (h^2) of 0.17 for the weight at 13 weeks. Higher values were found by VACCARO *et al.* (1968) and Dillard *et al.* (1972), cited by QUIJANDRIA *et al.* (1983). The results illustrate the potential of selection for live weight and less possibility for litter size.

The live weight of the guinea pig can reach values as high as 2 kg indicating a potential to be exploited by genetics and selection.

KAMPEMBA & HORNICK (2013) studied the effect of forage source on levels of copper and zinc in various samples from growing guinea pig in Lubumbashi (DRC). The preliminary results indicate that the concentrations observed in edible fractions appear to be safe for human intake. Nevertheless, caution should be taken when consuming the liver owing to its tendency to accumulate metallic trace elements.

INSECTS

As indicated by MALAISSE (1997) and relayed by NSEVOLO (2012), insects are reliable and sustainable sources of high-quality animal protein. The availability of these valuable sources of protein fluctuates significantly and is totally dependent on seasonal variations (Mapunzu 2002, cited by NSEVOLO 2012).

MALAISSE (2005) considers some one hundred and four families distributed in fourteen orders in human consumption of insects. In his work on the consumption of Lepidoptera (mainly caterpillars), Isoptera (termites), Orthoptera (locusts, grasshoppers, crickets) and Formicidae (ants), relaying the survey of GOMEZ (1988) concerning insect consumption in Congo, the author indicates that it represents more than 40 % of animal proteins in some parts of the country and that around Brazzaville, 40 g dry weight smoked caterpillars are consumed per day and in other parts of the continent values of 30-50 g dry weight of insects per person per day, mainly caterpillars, are not at all rare for several months.

In Bas-Congo, according to LATHAM (2002), gathering caterpillars is a seasonal activity, taking place in the rainy season. The author indicates that dried caterpillars contain 52.9 % of proteins, 15.4 % of fat, 16.9 % of carbohydrates and that a significant amount is exported to Europe (France and Belgium).

Entomophagy could become a challenge with a balance between consumption and conservation in the context of a sustainable production of insects.

In the recent study of NSEVOLO (2012), the eleven insect species consumed in the city of Kinshasa showed a great variability in protein, with highest value being found in Isoptera (74.76 ± 0.78 %), followed by Orthoptera (69.48 ± 0.46 %) and the nine species of Lepidoptera (Notodontidae and Attacidae) (60.29 ± 4.7 %).

Production of Animal Feed

Feed production is a major limiting factor of the development of animal production. If many smallholders primarily rely on self-produced crops or residues, the access to quality feed becomes crucial when it comes about to developing commercially viable structures. Regarding the different productions presented in this paper, this aspect is all the more true in the case of poultry production.

In Cameroun, the poultry sector seems to be the most developed animal sector but it has lived difficult times since decolonization. The Douala-Banga, Mvog-Betsi, Nkounden state poultry stations were merged but stopped their activities due to the consequences of the Structural Adjustment Programme. As a result of this long history of a large-scale poultry production, the country has a feed mill tradition since many years. At present, thirty-three enterprises are involved in the agro-industrial sector, allowing for economic competition between them.

On the opposite, in the DRC, the MIDEMA feed mill in Matadi is the only one producing animal feed. According to TOLLENS & HUART (2006), imports of wheat and wheat flour, rice, corn, sugar, beef, chicken, pork, fish such as "chinchard" (mackerel) and vegetable oil, continue to grow, but unfortunately the imported products are of lesser quality. The price of imported frozen "chinchard" (mackerel) of 1 USD/kg is to be compared with the local fish (5 USD/kg).

Conclusion

The demand for animal protein is significant in the Congo Basin. Because of demographics, this demand is growing. Considering that the consumption of bushmeat is an important source of protein for the rural and urban populations, this growth puts wildlife under strong pressure. The various measures for alleviating that overexploitation, as breeding of wild animals, control of hunting and education, are not likely to restore the lost equilibrium.

In this context, we must mobilize and provide sustainable and innovative solutions for the shortfall in protein. To achieve the expected results, applied research, development and extension are made in pilot farms promoting appropriate technologies in the context of a comprehensive approach to animal productions incorporating animal nutrition, health, genetics and selection, environment and management.

REFERENCES

BESBES, B. 2009. Genotype evaluation and breeding of poultry for performance under sub-optimal village conditions. — *World's Poult. Sci. J.*, **65**: 260-271.

BINDELLE, J. & PICRON, P. 2012. Le Cobaye: un petit herbivore facile à nourir dans des petites parcelles. — *Troupeaux et Cultures des Tropiques*, **4**: 11-16.

BINDELLE, J., ILUNGA, Y., DELACOLLETTE, M., MULAND KAYIJ, M., UMBA DI M'BALU, J., KINDELE, E. & BULDGEN, A. 2007. Voluntary intake, chemical composition and *in vitro* digestibility of fresh forages fed to Guinea pigs in periurban rearing systems of Kinshasa (Democratic Republic of Congo). — *Trop. Anim. Health Prod.*, **39**: 419-426.

DELVINGT, W., DETHIER, M., AUZEL, P. & JEANMART, P. 2002. La chasse badjoué: Gestion coutumière durable ou pillage de la ressource gibier? — *In*: DELVINGT, W. (Ed.), La forêt des hommes. Terroirs villageois en forêt tropicale africaine. Gembloux (Belgique), Presses agronomiques de Gembloux, pp. 66-92.

DILLARD, E. U., VACCARO, R., LOZANO, J. & ROBINSON, O. W. 1972. Phenotypic and genetic parameters for growth in guinea pigs. — *J. Anim. Sci.*, **34**: 193.

EDDERAI, D. & HOUBEN, P. 2002. Elevage et performances de reproduction et de croissance de l'athérure africaine. Résultats sur l'étude de sa reproduction en captivité = Rearing and reproduction and growth performances of the African brush-tailed porcupine. Study results on its reproduction in captivity = Cria y rendimiento de la reporduccion y del crecimiento del *Atherurus africanus*, roedor africano. Resultado sobre el estudio de su reproduccion en cautiverio. — *Revue d'élevage et de médecine vétérinaire des pays tropicaux*, **55** (4): 313-320.

FA, J. E., CURRIE, D. & MEEUWIG, J. 2003. Bushmeat and food security in the Congo Basin: linkages between wildlife and people's future. — *Environmental Conservation*, **30** (1): 71-78.

GOMEZ, M. I. 1988. A resource inventory of indigenous and traditional foods in Zimbabwe. — *Zambezia: The Journal of Humanities of the University of Zimbabwe*, **15** (1): 53-74.

HARDOUIN, J. 2005. The Minilivestock: Environment, Education, Research, and Economics. — *In*: PAOLETTI, M. G. (Ed.), Ecological implications of minilivestock. Potential of insects, rodents, frogs and snails. Enfield, NH (USA), Science Publishers, pp. 19-24.

HARDOUIN, J., DEMEY, F. & FRANSOLET, M. F. 1991. Le cobaye *Cavia porcellus* L., animal de boucherie en pays tropicaux. — *Annales de Gembloux*, **97**: 69-80.

HORTA, K. 2009. Global Climate, Politics in the Congo Basin, Unprecedented Opportunity or High-risk Gamble? CGGA Center for Global Governance & Accountability. — Washington D.C. and Lisbon, Heinrich-Böll-Stiftung Berlin.

KAMPEMBA, F. & HORNICK, J.-L. 2013. Effect of forage source on levels of copper and zinc in various samples from growing guinea pig, Lubumbashi, RDC: preliminary results (personal communication).

LATHAM, P. (Ed.) 2002. Some edible caterpillars and their food plants in Bas-Congo, Democratic Republic of Congo. — Forneth, UK, 49 pp.

MALAISSE, F. 1997. Se nourrir en forêt claire africaine. Approche écologique et nutritionnelle. — Gembloux (Belgique), Les Presses Agronomiques de Gembloux / Wageningen (the Netherlands), Centre technique de Coopération agricole et rurale (C.T.A.).

MALAISSE, F. 2005. Human consumption of Lepidoptera, Termites, Orthoptera, and Ants in Africa. — *In*: PAOLETTI, M. G. (Ed.), Ecological implications of minilivestock. Potential of insects, rodents, frogs and snails. Enfield, NH (USA), Science Publishers, pp. 175-230.

MAMMERICKX, M. 1986. Les médecins vétérinaires en Afrique centrale à l'époque coloniale belge 1885 à 1960. — *In*: Liber Memorialis, de l'art à la science, ou 150 ans de Médecine vétérinaire à Cureghem. Bruxelles, Edition des Annales de médecine vétérinaire, 584 pp.

MAPUNZU, M. P. 2002. Contribution de l'exploitation des chenilles et autres larves comestibles dans la lutte contre l'insécurité alimentaire et la pauvreté en République démocratique du Congo. — *In*: N'GASSE (Ed.), Contribution des insectes de la forêt à la sécurité alimentaire. L'exemple des chenilles d'Afrique Centrale. Rome, FAO.

MBETE, R. A. 2012. La consommation de la viande de chasse dans les ménages de Brazzaville, Congo. — Thèse de doctorat, Université de Liège.

MBETE, R. A., BANGA-MBOKO, H., NGOKAKA, C., BOUCKACKA, III Q. F., NGANGA, I., HORNICK, J.-L., LEROY, P. & VERMEULEN, C. 2011a. Profil des vendeurs de viande de chasse et évaluation de la biomasse commercialisée dans les marchés municipaux de Brazzaville, Congo. — *Trop. Conserv. Sci.*, **4** (2): 203-217.

MBETE, R. A., BANGA-MBOKO, H., RACEY, P., MFOUKOU-NTSAKALA, A., NGANGA, I., VERMEULEN, C., DOUCET, J. L., HORNICK, J.-L. & LEROY, P. 2011b. Household Bushmeat Consumption in Brazzaville, the Republic of the Congo. — *Trop. Conserv. Sci.*, **4** (2): 187-202.

MICHA, J.-C. 2013. Fish Farming in the Congo Basin: Past, Present and Future. — *In*: Proceedings of the International Conference on Nutrition and Food Production in the Congo Basin (Brussels, 30 September – 1 October, 2013), pp. 147-171.

MONDI IKOBO, S., MBETE, A. R., HORNICK, J.-L., LEROY, P. & BANGA-MBOKO, H. 2013. Exploitation et consommation d'athérure africain (*Atherurus africanus*, Gray 1842) dans le Bassin du Congo (submitted for publication).

MOULA, N., FARNIR, F., SALHI, A., DO DUC, L., VU DINH TON, LEROY, P. & ANTOINE-MOUSSIAUX, N. 2012a. Comparative evaluation of local poultry breeds status in Algeria, Vietnam and the Democratic Republic of Congo. — Proceedings of the 1st Poultry International Seminar.

MOULA, N. 2012b. Biodiversité avicole dans les pays industrialisés et en développement: caractérisation et étude des performances de production de races gallines

locales (Exemple de la Belgique, de l'Algérie, du Vietnam et de la République démocratique du Congo). — Thèse de Doctorat, Faculté de Médecine Vétérinaire, Université de Liége (ULg), 261 pp.

MOULA, N., DETIFFE, N., FARNIR, F., ANTOINE-MOUSSIAUX, N. & LEROY, P. 2012c. Aviculture familiale au Bas-Congo, République démocratique du Congo (RDC). — *Livestock Research for Rural Development*, **24** (5): Article 74.

NGOU NGOUPAYOU, J. D., KOUONMENIOC, J., FOTSO TAGNY, J. M., CICOGNA, M., CASTROVILLE, C., RIGONI, M. & HARDOUIN, J. 1995. Rearing unconventional livestock species: a flourishing activity. Possibilités de développement de l'élevage du cobaye en Afrique subsaharienne: le cas du Cameroun. — *World Animal Review*, **83** (2): 21-28.

NIBA, A. T., DJOUKAM, J., TEGUIA, A., KUDI, A. C. & LOE, J. O. 2004. Influence of Level of Cottonseed Cake in the Diet on the Feed Intake, Growth Performance and Carcass Characteristics of Guinea Pigs in Cameroon. — *Tropicultura*, **22** (1): 32-39.

NKIDIAKA, O. 2004. Les pratiques d'élevage en milieu urbain et périurbain de la ville de Kinshasa: synthèse générale des enquêtes. — *Troupeaux et Cultures des Tropiques*, **3**: 50-52.

NSEVOLO, P. M. 2012. Contribution à l'étude de l'entomophage à Kinshasa. Travail de fin d'études présenté en vue de l'obtention du diplôme de master complémentaire en protection des cultures tropicales et subtropicales. — Gembloux Agro-Bio Tech – ULg.

QUIJANDRIA, B., CHAUCA DE ZALDIVAR, L. & ROBISON, O. W. 1983. Selection in Guinea Pigs: I. Estimation of Phenotypic and Genetic. — *J. Anim. Sci.*, **56**: 814-819.

RISCHKOWSKY, B. & PILLING, D. (Eds) 2008. The state of the world's animal genetic resources for food and agriculture. — Rome, Food and Agriculture Organization.

TOLLENS, E. 2010. Potential Impacts of Agriculture Development on the Forest Cover in the Congo Basin. — Report, World Bank.

TOLLENS, E. & HUART, A. 2006. Les importations alimentaires et la protection douanière en RDC. Troupeau et culture des tropiques. — Kinshasa, Numéro spécial sur la politique agricole en RDC, CAVTK.

VACCARO, R., DILLARD, E. U. & LOZANO, J. 1968. Crecimiento del cuy del macimiento al Oestete. — *Memoria de la Assoc. Latinoamericana de Produccion Animal*, **3**: 115.

VERMEULEN, C. & DOUCET, J.-L. 2006. Stratégies nouvelles et recompositions sociales autour de la faune dans le Bassin du Congo. — *Base*, **10** (3): 251-257.

VUMILIA KASUKI, J. 2012-2013. Gestion des aides en agriculture urbaine tropicale et effets à court terme sur l'économie des ménages bénéficiaires. Une expérience réalisée en cuniculture par le Consortium d'Agriculture Urbaine de Butembo (Nord-Kivu, RDC). — Mémoire Master complémentaire MC-GRAVMT, ULg.

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Fish Farming in the Congo Basin: Past, Present and Future

by

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KEYWORDS. — Fish Culture; Congo Basin; National Aquaculture Development Strategy and Action Plan; DR Congo; Republic of Congo.

SUMMARY. — Fish culture has recently been introduced in Africa. It started in 1946 in Lubumbashi, DR Congo (Heenen ponds and Kipopo station), with two tilapia species from Moëro lake (*Oreochromis macrochir* and *Tilapia rendalli*). The good results recorded by the colonial administration were quickly extended to the whole country and to the neighbouring countries — the Democratic Republic of Congo, Rwanda, Burundi — and finally to all Africa. But the model was meant to make the food production self-supporting at community level. After independence, without the support of the public sector, the fish culture totally crashed and the production collapsed.

Currently, the fish farming sector in the Congo Basin (ten countries) is damaged. Extensive fish production in rural areas is insignificant due to the mismanagement of ponds (no fertilization, degenerated strain of tilapia, no feeding, etc.). Semi-intensive and intensive fish production systems have not yet been developed by any fish farmer (only a few exceptions such as the Belgian Technical Cooperation (BTC) Fish Culture Project in Katanga). The main reasons are: inappropriate development policies and lack of strategies and development plans of the subsector. Moreover, these multiple and uncoordinated interventions (bilateral, multilateral cooperation, many and various NGOs based on donations) have all followed approaches promoting subsistence aquaculture. These projects, without an exit strategy, have not tried to develop it into a profitable business capable of generating significant revenues and competitive finance themselves and creating paying jobs. Other constraints are: lack of fish-feed industries, difficult access to capital investment, lack and/or inadequacy of quality seed, lack of qualified staff and lack of production technologies control.

The future could be better as each country of the Congo Basin, with the help of the ACP FISH II Programme, has developed a national policy on fisheries and aquaculture approved by its government and national assembly. There is now a formal conviction to develop aquaculture with a clear action plan to solve the food fish

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problem at the technical, social and economic level. On the other hand, each country, with the assistance of the FAO and the ACP FISH II Programme, has also made a National Aquaculture Development Strategy and an Action Plan in order to address this challenge and to try to remove other barriers to this subsector development. This strategy provides policy makers and development agents the fundamental principles that should guide the development and implementation of programmes for sustainable development of the sector. In other words, it provides an operational framework within which any development plan for aquaculture will be developed.

In conclusion, at this step, all the instruments are in place to develop sustainable and profitable aquaculture in the Congo Basin, based on two key species of the world aquaculture that are African endemic, but they must be applied correctly.

1. Introduction

The watershed of the Congo, second only to the Amazon, covers an area of 3,822,000 km² (CICOS 2003) shared by ten countries (fig. 1): Angola (8 %), Burundi (0.2 %), Cameroon (2 %), Congo (7 %), Gabon (0.04 %), Central African Republic (CAR) (11 %), the Democratic Republic of Congo (DRC) (64 %), Rwanda (0.2 %), Tanzania (4 %) and Zambia (5 %). With a

Fig. 1. — The Congo Basin and its respective areas in its ten countries of origin (CICOS 2003).

backbone length of 4,700 km, the Congo in Kinshasa has an average flow of 41,000 m^3/sec, supplied by numerous tributaries. The main ones are Ubangui and Sangha (northern equator) and Kasai (southern equator), which have very good water resources conducive to the development of sustainable fish farming since 1972 although subject to some wave sahelization and kalaharization respectively north and south of the basin (CICOS 2003). The forest cover is still significant (1.6 million km^2 or 46 %) and mainly located in the DRC, where 10 % of the forest is flooded with a relatively small marlin range.

Unlike Asia, which saw the birth of this activity in China, where farmers have been developing it in a sustainable way for nearly three millennia, fish farming was introduced in sub-Saharan Africa (in 1930 according to some sources but actually in 1946 around Lubumbashi in the DRC) by colonial administrations as a subsistence food technique with some success, however, dwindled after independence.

Given the immensity of the Congo River Basin, shared with ten countries, it would take too long to make the state of the fish in each country. We shall merely indicate past, present and future of this activity in the DRC, which represents the largest area of the watershed (64 %). However, we shall briefly point to the current state of the fish in the other nine countries before concluding.

2. Democratic Republic of the Congo (DRC, Kinshasa)

In the DRC, the evolution of fish culture, although only recently introduced, has been rather chaotic.

2.1. Past

We can say that fish culture in sub-Saharan Africa was born in Congo just after the Second World War (1946) in the region of Lubumbashi (Heenen ponds and Kipoko station) where the Belgian colonial authorities domesticated two tilapia (*Tilapia* (*Oreochromis*) *macrochir* BLGR and *Tilapia rendalli* BLGR), the breeding of which was popularized and disseminated to the entire country. The spectacular results quickly interested neighbouring countries, where the technique rapidly developed with the main objective, *i.e.* to solve the supply of indigenous fish issues. After a short trial period followed a rapid expansion of the family fish farming model. In 1960, the DRC totalized 122,000 ponds covering an area of 4,000 ha belonging to 15,000 farmers

(MICHA 1974a). The main cultured species was *Tilapia* (*Oreochromis*) *nilotica,* which gets the best performances. The development was based on the creation of twenty-five main hatchery centres (*Centre d'Alevinage Principal* (CAP)) with some secondary centres across the country and an important extension service in each province. After 1960 (post-independence period), fish culture declined everywhere, which was considered by some authors as a resounding failure. A few years later, the reorganization of the country led the Ministry of Agriculture and Livestock to sign cooperation agreements (MINAGRI 2008a) with various bilateral and multilateral organizations for projects to boost aquaculture (1970-1990). Thus, for example, the French bilateral cooperation supported the creation of a Centre for Commercialization of vegetable and fruit products (CECOMAF) mainly in the area of Kinshasa; the U.S. cooperation (U.S. Agency for International Development (USAID)), through the Peace Corps project, developed family fish culture throughout the country; the Belgian bilateral cooperation, through its General Agency for Development Cooperation (AGCD), also developed a family fish culture project in areas of Kinshasa, Bandundu and Bas-Congo. These — sometimes competing — assistance projects had a common goal: to develop family fish farming in rural and suburban areas. All these projects were abandoned in 1990, after the ceasing of all cooperation resulting from political events (embargo). Calm returned, the Ministry of Agriculture and Livestock (MINAGRI), through its National Aquaculture Service (SENAQUA), in 1997 received support and material from the HIPC (Highly Indebted Poor Countries) under the name "Redevelopment Programme for the aquaculture sector in the DRC". The strategy of this programme (MINAGRI 2008b) was based on five components:

— Distribution of materials and installation of various equipment;
— Human capacity building through seminars and refresher courses for fish culture;
— Rehabilitation of some nursery main centres (CAP: Ngandajika, Kasangulu, etc.);
— Support to farmers for the design, construction and/or rehabilitation and management of their farms;
— Promotion of semi-intensive fish farming in peri-urban areas.

During this period, the MINAGRI, with the support of the FAO, updated the Master Plan for Aquaculture which was prepared in 1993 and had obviously never been developed.

The results of all these actions to boost fish farming were disastrous. The findings on the grounds show:

— Poorly constructed ponds (bad construction of dikes and pond plates, improper drainage systems, pond plates full of stumps and trunks, etc.);
— Mismanagement of fish ponds (degenerated strains of cultivated species, improper fish densities, inappropriate drainage techniques, ...);
— Lack of specialized feed mills for fish;
— Unavailability of certified fry (quantity and quality);
— Insufficient and ineffective technical support.

The causes of this disastrous situation (MICHA 1974a, MINAGRI 2008a) are many:

— Bad socio-political situation: unstable, dangerous and/or hostile;
— Multiple project initiatives in the field without precise definition of goals and exit strategy;
— Perception that aquaculture is an extra speculation for food consumption (subsistence fish farming);
— Lack of regulation for the aquaculture subsector;
— Lack of political stance and therefore political support for the subsector;
— Lack of strategy and development plan for the subsector.

In other words, all these projects were neither prepared nor perceived to develop a profitable business generating significant revenue and creating paying jobs.

2.2. PRESENT

Currently, aquaculture is almost abandoned in all provinces and its production is insignificant despite strong demand for fish consumption (import of horse mackerel more than 100,000 t/year). A small exception in the Katanga province (fig. 2), which receives support from the Belgian Technical Cooperation (BTC), is the Development Project (training and extension) of the Artisanal Fisheries and Aquaculture (Prodepaak 2008-2013).

The main results of Prodepaak are:

— Partial rehabilitation (fig. 3) of the Kipoko station (47/208 ponds);
— Renewal and development of interest in fish farming with 366 private ponds, covering an area of 2,161 are, restored according to standard technical criteria and producing an average of 4,000 kg/ha/year;

Fig. 2. — Heat maps of the Belgian-Congolese Development Project of the Artisanal Fisheries and Aquaculture (Prodepaak 2008-2013).

— Pond fertilization (manure poultry, pigs, goats, cows) and/or feed for fish (malt brewery, rice bran, floating pellets from Zambia) reorganized;
— Adequate training of technicians in fish culture (> 20 courses of 30 days for 20 to 30 people), especially in pond construction according to the standards and artificial reproduction of the African catfish (*Clarias gariepinus*);
— Training of sixteen fish culture managers (public and private sector) during sixteen months or more (construction, water supply, loading fish fry, fertilization and/or feed, agro-fish culture, production and sale of fingerlings of certified quality, harvest and sale-consumable fish, organization of the sector: from the water to the mouth);
— Facilities for water control with integrated fish farming gardening (vegetables) and small livestock (pigs, poultry, ...).

But all this is still little compared to the expectation of coaching more than 20,000 farmers in Katanga. What about the rest of the country?

Regarding the private sector, entrepreneurs in the region of Kinshasa (about ten), under the leadership of consultants for the Centre for Economic

Fig. 3. — Aerial view of the hatchery Kipoko, Katanga (photo: J.-P. Marquet 2010).

Development (CDE, EU), have formed a group called *Groupement Agro-Piscicole de Kinshasa* (GAPK, 2010) to exchange experiences, improve their practices, perform their production and sell fish fry, fingerlings as well as consumable fish. Also note that a new entrepreneur is preparing the establishment of a farm in Kinshasa and periphery (Kimpoko) to produce, in a near future, in semi-intensive (ponds) and intensive (concrete tanks) systems, 3,000 t/year with implementation of a feed mill plan for extruded floating pellets.

On the public side, the DRC received in 2012, following its request, the assistance of the African, Caribbean and Pacific Programme of the European Union ACP FISH II (EU), which supported the Ministry of Agriculture and Livestock (MINAGRI) to prepare a National Policy for Fisheries and Aquaculture. This national policy document in the DRC (MINAGRI 2012) was

submitted early 2013 to the parliament, which discussed the document that is now awaiting approval. Meanwhile, the MINAGRI received the support of the FAO to prepare a new law, the "Code of fisheries and aquaculture in DR Congo", adopted by the government early 2013 and discussed by the parliament in 2013. In addition, the FAO has supported the MINAGRI to prepare the strategic sustainable development of aquaculture in the DRC. Finally, the FAO has always supported the MINAGRI to prepare the Aquaculture Development Plan 2010-2015.

The Strategy for Sustainable Development of Aquaculture (MINAGRI 2008a) is an integral part of the National Policy on Fisheries and Aquaculture in the DRC, a favourable context based on three fundamental axes:

— Improve efficiency of production systems: accessibility to inputs (fingerlings, feed, capital, etc.);
— Improve services: extension, training of all stakeholders, research, marketing support (industry);
— Improve management: professionalization, application of the new law, aquaculture section (rules applied, ...), etc.

The Action Plan (MINAGRI 2008b) for Aquaculture (2010-2015) sets specific goals and how to reach them:

— Specifying the target species: tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*);
— Fixing the amount of fish to produce 150,000 t for 2015 in earthen ponds (3,200 ha), cages (24,000 m^3 for tilapia and 3,000 m^3 for catfish), concrete tanks (15,000 m^3 for tilapia and 4,000 m^3 for African catfish), number of farmers (4,000 for tilapia and 600 for catfish);
— Improving annual revenues from 316 to 5,580 US$;
— Specifying requirements: 580 extension agents, 430,000 t of feed;
— Setting the consumption of desirable fish to 7.6 instead of 5.8 kg/*per capita*/year.

To this end, the National Aquaculture Service was reorganized into five divisions: Administration; Extension Division; Monitoring and Evaluation Division; Finance Division; Technical Division and Aquaculture Development Division. Its mandate was clarified, which means increasing aquaculture production, diversifying production techniques (from extensive to intensive), evaluating and enhancing natural resources (valleys, rivers,

lakes, ...), promoting the development of aquaculture, designing and adapting policy aquaculture, promoting applied research (domestication of new species, profitability of production systems) and supervising farmers to improve their performance. The cost of this action plan for five years is estimated at US$ 106 million. It remains to be seen who will provide the necessary resources for its implementation.

In conclusion, the new institutional context seems very good but we will have to await the application of all these aquaculture documents and the actual development of aquaculture in the field in a near future.

2.3. Future

Around the world, aquaculture is a real "big bang" (Micha 2006): in 2013, almost one out of two fishes consumed worldwide comes from culture given the stability or even the fall of the catch worldwide since 1990 (FAO 2012). For the first time the world production of farmed fish has reached and even surpassed that of beef (fig. 4).

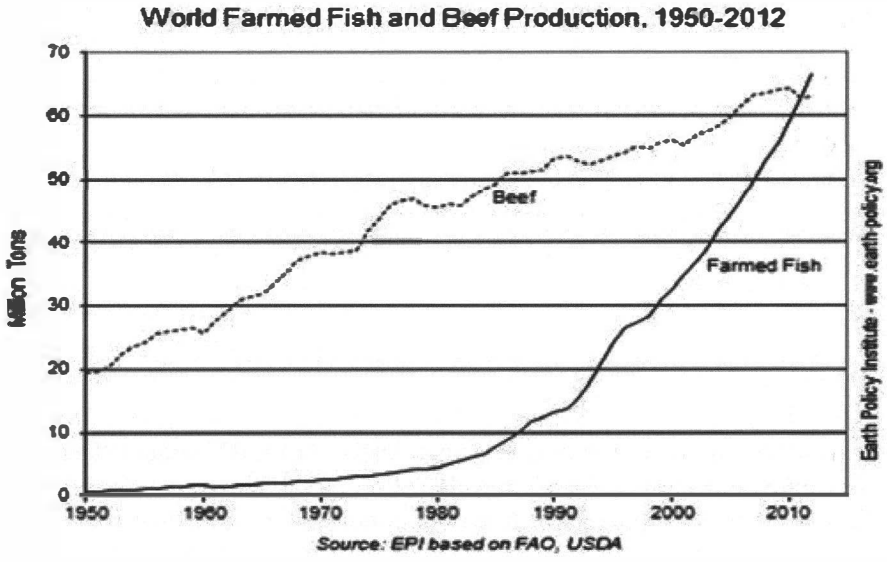


Fig. 4. — Evolution of the world annual global production of beef and farmed fish (1950-2012).

This is partly due to changes in diet (a healthier diet; polyunsaturated fatty acids) and a better welfare of elderly people (average fish consumption: 17.8 kg/person/year globally, 25 kg/person/year in Europe) but also to the fact that fish farming is much more effective and less costly than any other speculation with warm-blooded animals (poultry, sheep, cattle, pigs) to produce animal protein in man. Typical reasons for this are well known: fish, poikilotherm, does not maintain a constant high temperature; fish with a density close to that of water has a rather insignificant skeleton (maximum 4 % of the body weight against 20 % for some mammals); fish excreting ammonia better converts consumed protein. It follows that:

— Weight gain per gram of consumed food is 0.13 in cattle, 0.48 in broilers and 0.84 in catfish;
— Gain of protein per unit of consumed energy is 6 in beef, 23 in chicken and 47 in catfish;
— Farmed fish is the best compound feed converter (flour, extruded pellets floating) for food consumable by man (1.5 kg feed → 1 kg of fresh fish).

Many African countries have been slow to understand the need to develop aquaculture (PERCY & HISHAMUNDA 2001), but in recent years Nigeria, Egypt, Uganda, Zambia and Ghana have substantial productions that keep on increasing. It will therefore be necessary that the DRC, as others countries of the Congo watershed, follows their example because there is no other choice given the widespread overexploitation of all natural fish stocks in fresh, brackish and marine waters.

Immediately and independently of any research, the DRC should develop the culture of one of the world best species for aquaculture, whose culture is well known and well controlled for a long time (MICHA *et al.* 1975, KESTEMONT *et al.* 1989, LAZARD 2007), namely *Oreochromis niloticus*, an endemic species of Africa (fig. 5), introduced and produced everywhere in the world (World production in 2012: 3.4 million tons in sales prices, output fish culture: 1-2 US$/kg).

To do this, the DRC should first develop good strains of *O. niloticus*, genetically improved and thus growing rapidly. The GIFT strain ("Genetically Improved Farmed Fish") developed around 1987 by the World Fish Center in the Philippines, which is used throughout Asia (eleven countries), has been introduced in Central America (Costa Rica), Latin America (Brazil) and, more recently, in Africa (Zimbabwe, Zambia) despite the reluctance of scientists because of the risk of genetic pollution of indigenous African

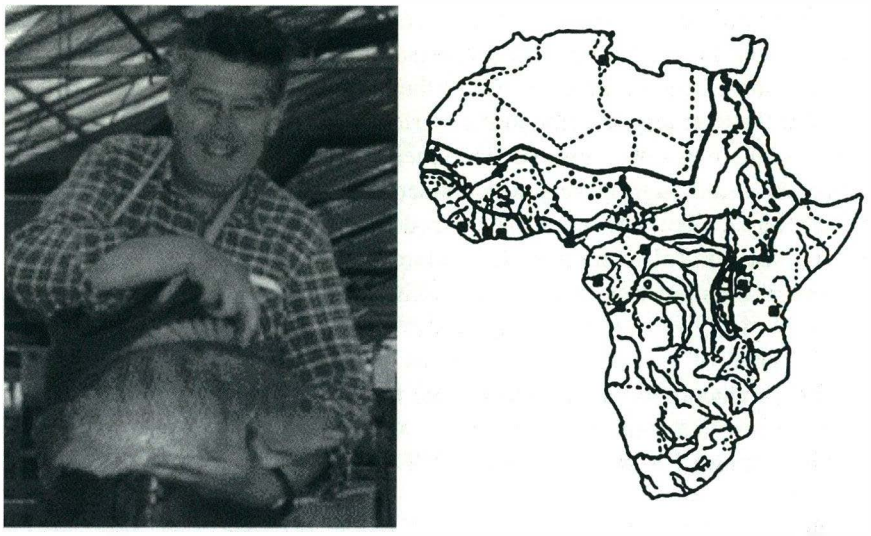


Fig. 5. — *Oreochromis niloticus* (photo) and its original distribution in Africa (black line).

strains. To avoid this problem, however, it would be better to use new selected strains from various local strains, such as SON ("Source of the Nile") developed in Uganda according to a similar GIFT scheme from three populations — *O. niloticus* from Lake Victoria, Lake Kyoga and Lake Albert — and suitable for medium altitudes (~ 1000 m) without marked winter (D. Desprez, pers. comm). Note that Rwanda, as part of an ADB project, has bred two natural strains from Lake Albert and Lake Victoria and distributed fingerlings in rural areas, but the "Rwanda Agricultural Board" (RAB) plans to start a breeding programme according to GIFT at Kigembe station (1,791 m) in 2014. At high altitudes, the strain *niloticus* Manzala Stirling could also give good results (J. Magnée, pers. comm.), but this requires experimental verification, appropriate equipment and a rigorous broodstock management, otherwise the benefit of the selection can be quickly lost. For fish culture in plain, it would be better to use a strain of low altitude, such as "*niloticus* Akosombo" strain, attempted in Ghana but which unfortunately (J. Magnée, pers. comm.) has high aggressiveness and a still relatively low (4 g/d) and limited growth (curve growth CAP: 350 g) indicating that the GIFT protocol does not automatically lead to success. These few non-exhaustive data indicate that it would still be desirable to develop a regional network that streamlines research and its application in the Congo watershed. In any case, from a good selected strain you have to go to the culture of monosex

male with fry of the same age and of certified quality, possibly for limited amounts by manual sexing or sex reversal with methyltestosterone added to the feed during the first four weeks of the fry's life (KESTEMONT *et al.* 1989). Most of the tilapia production in the world is being done by this sex reversal, which is increasingly contested since methyltestosterone residues have been detected — although in very low concentrations — in consumed fish. The future may evolve to a super male/pseudofemale technique.

The sex control technique (C. Mélard & D. Desprez, pers. comm.) by hormonal manipulation of the system XX/XY includes four stages:

— Reversal of sex undifferentiated larvae by ethinyl-oestradiol leading to the production of 100 % phenotypic females 50 %-50 % XX and XY;
— Crossing XY females with males XY leading to 25 % females XX, 50 % males XY and 25 % males YY

M XY	*I*	*F* XY	X	Y
X			**XX**	**XY**
Y			**XY**	**YY**

— Crossing males YY with females XY and sex reversal with ethinyl-oestradiol leading to 50 % females XY and 50 % females YY

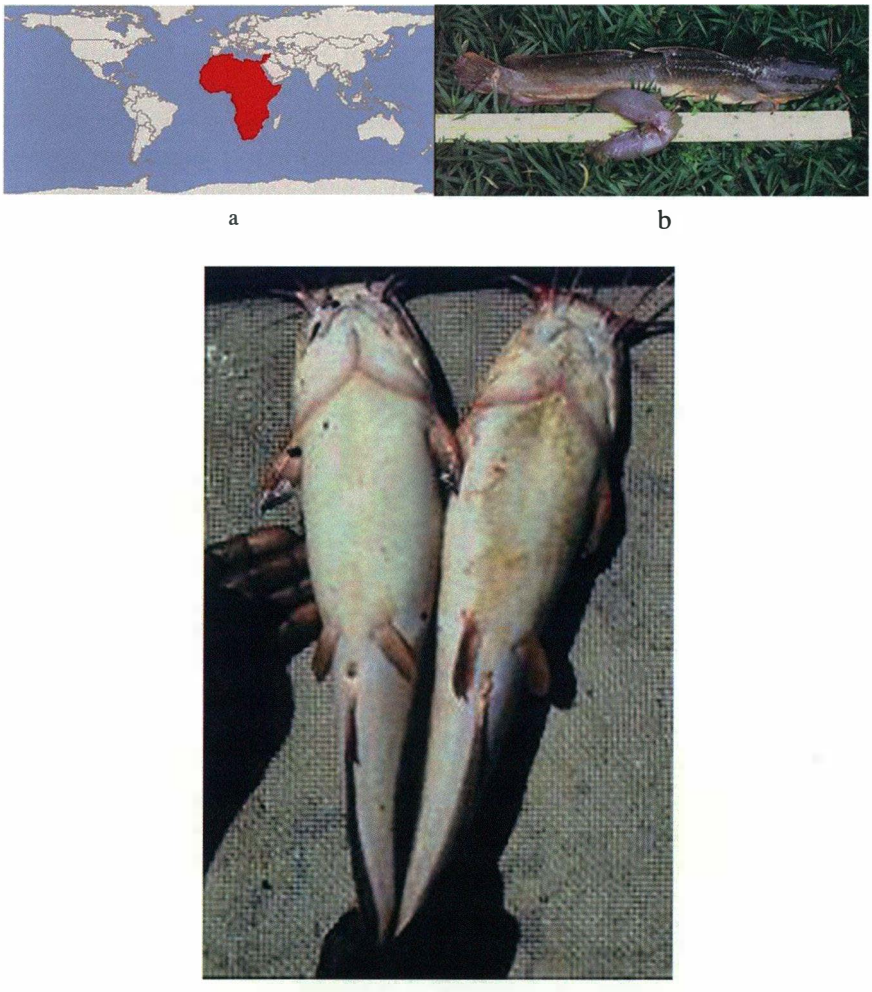
YY	*I*	XY	X	Y
Y			**XX**	**XY**
Y			**XY**	**YY**

— Crossing males YY with females YY leading to 100 % males without hormone residues for the commercial production.

However, this technique inversion/detection of genotypes, based on the sex ratio of offspring, is a factor which is currently limiting the amplification technique on an industrial scale (D. Desprez, pers. comm.). Indeed, in practice, we have to find females compatible with the males which will give 100 % YY males (J. Magnée, pers. comm.). Nevertheless, it should be noted that the Dutch private company Tilaqua trains technicians to this innovative practice and routinely provides super YY male/pseudofemale strains with some success but sometimes still with a high mortality.

A second species endemic to Africa, the African catfish, *Clarias gariepinus* Burchell (fig. 6), which has reached world record biomass (> 400 kg/m^3 of water) in intensive farming system mastered since the 1970s (DE KIMPE &

MICHA 1974, DUCARME & MICHA 2003, MICHA 1974b, MICHA 1975) with significant productions outside Africa (China, Vietnam, Brazil, etc.), should also be quickly produced in the DRC, given the strong local demand for this species (5 to 10 $/kg fresh weight). The techniques are relatively simple but the artificial reproduction and rearing ("fingerlings" of 10 g), which is now taking place on a large scale in Nigeria, where this kind of fish culture is strongly developing in ponds and in concrete tanks (intensive production units of 50 t/year), must be mastered.



a b

c

Fig. 6. — African catfish, *Clarias gariepinus*: (a) original geographical distribution; (b) female with mature ovaries (high fertility: 60,000 eggs/kg); (c) female (left), male (right).

In this regard, efforts for more than ten years — including the support of the Association for the Promotion of Education and Training Abroad (APEFE) and the Centre for Economic Development (CDE, UE) — on private farms in the Kinshasa region to train technicians able to master the techniques of reproduction and rearing, are finally successful. For example, the small private farm of S. Mutambwe to M'Binza Pigeon, Kinshasa (fig. 7), with his technician F. Kadima trained at Aquafarm Tihange (Belgium), produces with 5 ♀ (1-2 kg) of *Clarias gariepinus* and 10 ♂, an average of 850 g eggs always giving about 500,000 fertilized eggs, whose 360,000 living larvae give, six weeks later, some 180,000 fry (fingerlings 5 g) at a cost of ~0.1 US.$/piece, which are sold at a price of ~0.3 US$/unit. This type of production can be renewed every two months if the females are well fed, but with a rest period in July/August. Well-practiced, reproduction and rearing of African catfish is profitable and also serves to continuously supply producers specialized in the breeding of the market size of this popular fish (selling price 5-10 US$).

a

b

Fig. 7. — (a) Artisanal hatchery for catfish builded by S. Mutambwe at M'Binza Pigeon, Kinshasa; and (b) full tank of African catfish fry of about 0.5 g.

The choice of fish species to bring under cultivation in the immediate future is clear. Remains to be solved sustainably: pond fertilization and artificial fish feeding. For fertilization, we refer to the multiple possibilities (MICHA 1985; SYMOENS & MICHA 1995; RUKERA TABARO *et al.* 2005, 2012) of agro-fish culture (rice-fish, vegetables-fish, etc.) and culture with livestock (pigs-fish, poultry-fish, rabbits-fish, etc.), which are already more or less practised here and there in the DRC. However, for the artificial feeding of fish (TACON 2004, TACON *et al.* 2009) it is necessary to understand the need to develop semi-intensive to intensive fish farming. The latter requires feed-balanced performance and extruded floating pellets for adequate and profitable results because feed represents 50 to 70 % of the production cost for farmed fish. If the revival programme for agriculture in the DRC is properly done with processing products, the DRC will face a huge potential of by-products to enhance, and implementing a good strategy (appropriate mix of local by-products) could be of benefit to intensive fish production systems. In this regard, to convince any Congolese farmer of the need to feed fish wisely, here's a little basic reminder.

For the constitution of the body, fish, like any living organism, needs essential nutrients:

— **Proteins**, especially developed from the ten essential amino acids, including lysine and methionine, which are often deficient if you are not careful. These proteins are essential for developing muscles and other tissues: enzymes, hormones, eggs and sperm. Common sources of these proteins generally are: fish meal, soybean oil, cotton seed cake, groundnut, palm nuts, malt brewery, etc.
— **Lipids** (fats, long fatty acids (C18, C20) especially ϕ3 and ϕ 6), essential for the development and functioning of the brain, the nervous system, cell membranes, ovaries, hormones, etc. Common sources of these fats are animal fats (fish) and vegetables (soybean, cotton, peanuts, etc.). Also note that these lipids are essential carriers of fat-soluble vitamins.
— **Vitamins**: two categories: fat-soluble vitamins regulating the metabolism of structural units (*e.g.*, vitamin D and bone metabolism) and water-soluble vitamins providing energy transfers.
— **Minerals**, essential for the development of the skeleton and various functions. A vitamin and mineral complex that meets the needs of fish is generally added to compound feed.
— **Carbs or carbohydrates**: not required for the constitution of the body but used in diets because they are a source of cheap energy, provided they are digestible (*e.g.* starch). Indigestible hydrates carbon are simply excreted. However, they are essential to produce floating pellets (starch expansion during extrusion). Common sources include wheat bran, rice bran, corn bran, cassava, etc.

Note that in order to grow and move, fish still needs energy from proteins, lipids and/or carbohydrates. To properly feed fish you simply have to adapt the food formulation to their nutritional needs. For tilapia, *O. niloticus* and African catfish, *C. gariepinus*, nutritional needs are well known and can be met by various combinations of feed by-products. However, it must be kept in mind that there is no single food ingredient that contains all necessary nutrients for a balanced diet. The big challenge will be to:

— Make less expensive food meeting the nutritional requirements with the most economic combination of locally available by-products (they are constantly changing);
— Make effective programmes by checking the quality of available by-products (note the digestibility of each ingredient);
— Use applied research to develop quality feed while checking its performance on fish growth and the economic profitability of the production;
— Promote an interactive approach between farmers, researchers and feed producers.

Among the increasingly raised objections against the development of fish farming, mainly against the "bad" fish culture, namely farming predators at the end of the food chain (salmon, tuna, captains, bass, bream, etc.), we must cite the use of wild fish meal to feed farmed fish, turning it into an unsustainable practice (2.5 kg of wild fish to produce 1 kg of salmon). This is the case neither for tilapia nor for catfish, which are at the bottom of the food chain in the aquatic ecosystems. They can be fed with a relatively low protein content (28 % for tilapia, 32 % for catfish), which may come mainly from plant protein avoiding even the use of fish meal (tab. 1). Thus, there is no doubt about the future of fish farming, but it must grow responsibly and sustainably.

Table 1
Composition of extruded floating pellets containing 32 % protein for catfish with and without fish meal (modified from Li *et al.* 2003)

Feed with fish meal		**Feed without fish meal**	
Ingredients	%	*Ingredients*	%
Soybean meal	35	Soybean meal	34,6
Cotton meal	10	Cotton meal	12
Fish meal	4	Fish meal	0
Meat scraps, bone, blood	4	Meat scraps, bone, blood	8
Corn	30	Corn	30,3
Wheat bran	15	Wheat bran	15
Fat	1,5	Fat	1,5
Vitamino-mineral complex	Included	Vitamino-mineral complex	Included

In addition, intensive fish farming involves providing fish feed adapted to the size of their mouth, which constantly increases from fry to fingerling and market size. It is therefore necessary to technically produce meals and pellets with dimensions adapted to the different stages of farming (fig. 8).

Fig. 8. — Different sizes of powder and pellets to feed the fish at different stages of farming.

Given the extraordinary biodiversity of fish in Africa, there obviously are still a lot of research opportunities, not only for the domestication of new species of freshwater (*Schilbeidae*, *Parachannidae*, *Mochocidae*, *Distichodontidae*, etc.) and marine water fish (*Haemulidae*, *Carangidae*, *Polynemidae*, etc.) but also of crustaceans (*Palaemonidae*) and molluscs. However, the question is: why domesticate new species if it is to let them grow on other continents? There clearly is an urgent need to start with a high production in Africa and in the Congo Basin with these two flagspecies: tilapia and catfish.

Finally, among the concrete immediate prospects, the Ministry of Agriculture (MINAGRI) of the DRC could count on the support of the Belgian Technical Cooperation (BTC) for a new project to boost fish farming (in addition to the Bandundu programme for agriculture (2013-2017), districts Kwilu and Kwango) and of the *Association pour la Promotion de l'Education et de la Formation à l'Etranger* (APEFE) (2014-2016) to encourage extensive fish farming (family) and to try out semi-intensive fish farming (tilapia/catfish) in the district of Lower River, Province of Bas-Congo.

3. Other Countries in the Congo Watershed

I will now briefly discuss fish culture in the other nine countries of this vast basin.

3.1. Angola

The aquaculture in Angola (2013, 2013a) develops according to a strategy adopted by the Government to fight poverty. Although the National Institute for Fisheries Research and the Institute of Artisanal Fisheries have been evaluating its potential since 2004, aquaculture remains undeveloped and focuses on small rural freshwater fish with native species in some provinces. However, some private commercial enterprises (Kifangondo & Kwanza River) have emerged with the support of Brazil. It is possible that this activity will develop shortly with the support of Brazil to the Angolan Directorate of Aquaculture.

3.2. Burundi

Introduced in 1950, extensive fish farming based on the distribution of fry (FAO 2013, 2013b) from two state stations (Karusi & Isaiah) developed erraticly through different successive projects (Colonial Administration, Belgian AIDR, UNDP, USAID, ADB). Production has reached its peak: 120 t/year of tilapia (*Oreochromis niloticus*) provided by 2,000 farmers (FAO 2013b) operating 2,500 small ponds (in total 60 ha). Currently, the activity is being hardly practised and production is insignificant although the potential remains high for an integrated agro-pisciculture (rice-fish farming, with livestock: poultry-fish, pigs-fish, rabbits-fish).

3.3. Cameroon

Also introduced after the Second World War by the colonial administration, fish farming has developed up to its peak: more than 40,000 farmers (FAO 2013, 2013c) producing about 5,000 t/year of tilapia (*Oreochroms niloticus*), catfish (*Clarias gariepinus*), carp (*Cyprinus carpio*) and *Heterotis niloticus*. Currently, the activity remains very marginal and has difficulties to come to a true development. However, the recent strategic framework for sustainable aquaculture development, clarifying the respective roles of government, private sector and producers, plans to enhance the potential of freshwater aquaculture — brackish (shrimp at Kribi) and marine water — through the development of efficient production systems, access to inputs, training, research, extension, etc.

3.4. Republic of Congo

Fish farming in the Republic of Congo (FAO 2013d) also started in the 1950s with the *Centre Technique Forestier Tropical* (CTFT) creating 8,400 ponds producing 1-2 t/ha/year of tilapia. From 1968 to 1991, regional UNDP/FAO and World Bank (WB) projects supported the research, training and extension of tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*), intensifying the production to nearly 4 t/ha/year and annually producing 250 t/year. However, due to lack of monitoring and political unrest (1994, 1997 and 1998), fish culture has completely collapsed and only a few private entrepreneurs on the outskirts of Brazzaville — the *Groupe Agro-Piscicole de Brazzaville* (GAPB) —, supported by the Centre for the Development of Enterprise (CDE) of the European Union (EU), are involved in this trade action. Yet, the natural conditions are very favourable for aquaculture in the Republic of Congo. It could be redeveloped quickly, taking into account strategic efforts of the current government (the new Code of Fishery and Aquaculture, the National Development Strategy and the Action Plan for Aquaculture).

3.5. Gabon

Fish farming rural type (units of 2 to 3 ponds of 2 to 5 are) started under the leadership of the *Centre Technique Forestier Tropical* (CTFT) around 1950 (FAO 2013e), with tilapia (*Oreochromis niloticus*) in classes of mixed age, sometimes associated with a small predator (*Hemichromis fasciatus*), with an output of 1 to 2 t/ha/year. A company, SODEPAL, even developed, in the southern region, the production of monosex male tilapia (chemical sexing with methyltestosterone) and had an annual production of about one hundred tons. In 2006, domestic production reached 126 t in state stations, among which the ancestral Oyem station and 89 private farms, a total of 456 ponds. New recent efforts are being made to provide intensive fry production in semi-closed circuit with *Clarias gariepinus* in the Libreville station, but the commercial chain does not seem to have been taken into consideration. Nevertheless, the demand for fish exceeds the supply and natural conditions are very favourable. On the other hand, as institutional measures and arrangements are very consistent, fish culture should develop into the country though it is still at an administrative level.

3.6. Central African Republic

As in other former French colonies, the CTFT promoted, around 1950, rural fish farming, accompanied by a post-independence revival through UNDP/FAO and World Bank (WB) regional projects from 1968 to 1991, to support research, training and extension of aquaculture of tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*). This has promoted 8,500 small private producers (FAO 2013f) intensifying their production to nearly 4 t/ha/year and annually producing 360 t/year. Since then, political turmoil reaching its peak in November 2013 has destroyed this activity like any other. Nevertheless, the natural conditions in the south of the country and the interest of farmers are very supportive of this activity which, no doubt, will resume magnitude when conditions return to normal.

3.7. Rwanda

Fish farming was introduced, as in the DRC, by the Belgian colonial administration after the Second World War by creating two large southern state stations, Kigembe and Rwasave (Sarnissa 2013), supplying hundreds of private rural ponds with tilapia fingerlings. As elsewhere, fish farming declined after the independence of the country in 1962. Since then, several projects (EDF, CRSP, KUL, University of Namur) have attempted to revive activity within MINAGRI, the National University of Rwanda (UNR) and NGOs like HELPAGE, which even created a new fish farm in Ruhengeri to supply certified quality fry (tilapia and catfish) to many rural farmers in the periphery. It seems these efforts are paying off and led to the introduction of rural fish farming, whose poultry cum fish and rabbit cum fish culture experiences some development.

3.8. Tanzania

In Tanzania, fish was introduced by the British colonial administration around 1949, with the culture of rainbow trout (*Oncorhynchus mykiss*) and tilapia trials in Korogwe and Malya station (Balarin 1985; FAO 1990, 2013g; ECA/FAO 1985) accompanied by the promotion of small rural ponds — in 1968, there were 8,000 of them — with tilapia, but poor production. Currently, there are a little more than 14,000 private farmers, but their production is still low, the activity remaining marginal. Note that since 1989, the small seaweed species *Eucheuma spinosum* and *Kappaphycus cottonii* are growing on the

coast. Finally, aquaculture has great potential but mainly on the sea coast (shrimp, seaweed, marine fish, etc.).

3.9. Zambia

In the early 1950s, the first farmed tilapia trials aroused interest for fish culture, which exploded after the successful introduction of carp imported from Eastern Europe (FAO 2013h, ECA/FAO 1985, Mwango *et al.* 1999). Several farmers from various regions invested in this practice which fell down after independence. But various agencies, such as the United Nations Development Programme (UNDP), the UN High Commissioner for Refugees (UNHCR), the United States Agency for International Development (USAID), the International Agency cooperation of Japan (JICA), the Norwegian Agency for Development (NORAD) and the United Nations Food and Agriculture Organization (FAO), tried to promote fish farming (Soma *et al.* 1999). Thus in recent years, Zambia has revived a commercial fish culture based on compound feed (floating pellets) for the production of tilapia (*Oreochromis niloticus*), carp (*Cyprinus carpio*), catfish (*Clarias gariepinus*) and introduced crayfish (*Procambarus clarkii*). These productions strongly developed in 2010, reaching 10,000 t/year. In addition, the fisheries legislation has been revised by introducing aquaculture; a national aquaculture strategy oriented towards the private sector has been formulated; and the Zambian government has set up an appropriate institutional framework. Currently, more than 6,000 small farmers and 15 large private farms are producing tilapia, carp and catfish in over 13,000 ponds spread across 9 provinces. Four commercial enterprises, among which "Lake Harvest", are breeding fish in cages of 216 m^3 (6 x 6 x 6 m) in Lake Kariba, with a production of 3.5 t/cage. Zambia is clearly under way to exploit its great potential and is actually on the right track for the sustainable development of aquaculture.

4. Conclusions and Prospect

The ten countries of the Congo watershed have in a recent past (post World War II) introduced and developed tilapia farming, which has known a spectacular boom followed by a general disinterest. The findings are staggering: poor construction, poor management, lack of fertilization and/or feed, poor seed production, all resulting from or lack of ineffective technical

support. The causes of this disastrous situation are the unstable and even hostile and dangerous socio-political context, the lack of a precise definition and objectives for multiple bilateral or multilateral projects and NGOs, the absence of regulations for the subsector of aquaculture and, ultimately, the absence of any political stance, strategy or real action plan with substantial resources.

Currently, fish farming in the Congo Basin is stammering. In Angola, Burundi, the Central African Republic and Tanzania it is almost non-existent. In Cameroon, the Republic of Congo, Gabon, Rwanda and the DRC fish culture does not decrease but activities and production are very limited although supported by various state projects and bilateral or multilateral cooperation. One country, Zambia, is seriously developing this sector, whose production becomes significant, creating jobs and interesting incomes, thanks to the solving of two classic problems: fingerling production of good strain and certified quality and output of extruded floating pellet.

Given the increasing demand for fish as a result of the growth of human populations, food adaptations for better health and overexploitation of wild stocks, the countries of the Congo Basin, like other African countries (Egypt, Nigeria, Ghana, Zimbabwe, Zambia, etc.), will have to develop fish farming such as the farming of *Oreochromis niloticus* and *Clarias gariepinus*, two African endemic species among the best in the world for fish culture and which have been introduced on all continents, where they have been subject to much larger farming than in Africa. The context is now much more favourable since most countries have adapted and modernized their law on fisheries by adding a part on aquaculture, developed a National Policy on Fisheries and Aquaculture approved by their parliaments, established a strategy and a concrete action plan for the development of responsible and sustainable aquaculture. However, special attention should be given to the acquisition and management of good strains of fish adapted to different climatic conditions in the watershed of the Congo and to the production of fry monosex male of certified quality. In this regard, the sex reversal methyltestosterone, currently still widely practised, is increasingly challenged, because of residues of the substance found in very low concentrations in consumed fish. The future may go to the super YY male/pseudofemale technique to produce fry *O. niloticus* all males, providing market fish without hormone residues.

To grow the fry, it remains to solve sustainable pond fertilization and artificial feeding. For fertilization, we refer to the multiple possibilities of agro-fish culture (rice-fish, vegetables-fish, etc.) and livestock (pigs, poultry, rabbits, etc.) cum fish culture, which are already more or less practised here

and there (the DRC, the Republic of Congo, Rwanda, etc.). But for fish culture in intensive systems, it is absolutely necessary to get balanced feed such as floating extruded pellets. The stimulus package programmed for agriculture in Congo should lead to a huge production of by-products through appropriate feed mixtures, which could benefit intensive fish production systems. We must therefore develop research to produce quality foods that meet the identified needs of tilapia and catfish checking their performance on fish growth and economic profitability.

Obviously, responsible and sustainable aquaculture must be developed in all countries of the Congo Basin starting with two African endemic species (*O. niloticus* and *C. gariepinus*) because there is no alternative to supply African populations with fresh fish (animal protein and polyunsaturated fatty acids of high quality) at a low ecological and energetic cost and at an acceptable price for human populations with a limited purchasing power.

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REFERENCES

BALARIN, J. D. 1985. National reviews for aquaculture development in Africa: Tanzania. — FAO Fish Circ., (770.7), 96 pp.

CICOS 2003. http://www.cicos.info/siteweb/index.php?id=121&L=0

DE KIMPE, P. & MICHA, J.-C. 1974. First guidelines for the culture of *Clarias lazera* in Central Africa. — *Aquaculture*, **4**: 227-248.

DUCARME, C. & MICHA, J.-C. 2003. Technique de production intensive du poisson chat africain, *Clarias gariepinus*. — *Tropicultura*, **21** (4): 189-198.

ECA/FAO 1985. Rural Fish Culture Development and Technology Transfer in Eastern and Southern Africa. — FAO Tech. Pap., 248, 47, 35 pp.

FAO 1990. Fish Culture Development in Zambia. Project findings and recommendation. — FAO Final Technical Report, 205 pp.

FAO 2012. La situation mondiale des pêches et de l'aquaculture 2012. — Rome, FAO, 241 pp.

FAO 2013. http://www.fao.org/fishery/countryprofiles/search/en

FAO 2013a. ftp://ftp.fao.org/FI/DOCUMENT/fcp/en/FI_CP_AO.pdf

FAO 2013b. ftp://ftp.fao.org/FI/DOCUMENT/fcp/fr/FI_CP_BI.pdf

FAO 2013c. ftp://ftp.fao.org/FI/DOCUMENT/fcp/fr/FI_CP_CM.pdf
FAO 2013d. ftp://ftp.fao.org/FI/DOCUMENT/fcp/fr/FI_CP_CG.pdf
FAO 2013e. ftp://ftp.fao.org/FI/DOCUMENT/fcp/fr/FI_CP_GA.pdf
FAO 2013f. http://www.fao.org/fishery/facp/CAF/fr
FAO 2013g. http://www.fao.org/fishery/countrysector/naso_tanzania/fr
FAO 2013h. http://www.fao.org/fishery/countrysector/naso_zambia/fr
KESTEMONT, P., MICHA, J.-C. & FALTER, U. 1989. Les méthodes de production d'alevins de *Tilapia nilotica*, ADCP/Rep/89/46. — Rome, FAO, 132 pp.
LAZARD, J. 2007. La pisciculture des tilapia. — *Cahiers Agricultures*, **18** (2-3): 174-82.
LI, M. H., MANNING, B. B. & ROBINSON, E. H. 2003. Effect of dietary protein concentration and stocking density on production characteristics of pond-raised channel catfish *Ictalurus punctatus*. — *J. World Aquacult Soc.*, **34** (2): 147-155.
MICHA, J.-C. 1974a. La pisciculture africaine. Espèces actuelles et espèces nouvelles. — *In*: RUWET, J.-C. (Ed.), Zoologie et Assistance Technique. Liège, Edit. Fulreac, 381 pp.
MICHA, J.-C. 1974b. Fish population study of Ubangui river: trying local wild species for fish culture. — *Aquaculture*, **4**: 85-87.
MICHA, J.-C. 1975. Synthèse des essais de reproduction, d'alevinage et de production chez un silure africain, *Clarias lazera*. — Symposium CIFA, 75 SE 5. Rome, FAO, 23 pp.; *Bull. Franç. de pisciculture*, **256**: 77-87.
MICHA, J.-C. 1995. L'aménagement des écosystèmes agro-piscicoles d'eau douce en milieu tropical. Résumé, conclusions et recommandations. — *In*: SYMOENS, J.-J. & MICHA, J.-C. (Eds.), Actes du Séminaire «L'aménagement des écosystèmes agro-piscicoles d'eau douce en milieu tropical» (Bruxelles, 16-19 mai 1994), pp. 619-627.
MICHA, J.-C., RUWET, J.-C., VOSS, J. & HANON, L. 1975. Biologie et élevage des *Tilapia*. — Symposium FAO, CIFA, SR 8. Rome, FAO, 32 pp.
MICHA, J.-C. 1985. L'aménagement des marais tropicaux en écosystèmes agro-piscicoles. — *Bull. Séances Acad. r. Sci. Outre-Mer*, **31** (3): 371-389.
MICHA, J.-C. 2006. Pas d'avenir sans pisciculture: le *big bang* piscicole. — *Bull. Séanc. Acd. R. Sci. Outre-Mer*, **52** (4): 433-457.
MINAGRI 2008a. Stratégie de Développement Durable de l'Aquaculture en République Démocratique du Congo (inédit, 22 pp.).
MINAGRI 2008b. Plan de Développement de l'Aquaculture en République Démocratique du Congo 2010-2015 (inédit, 49 pp.).
MINAGRI 2012. Politique Nationale de la Pêche et de l'aquaculture en République Démocratique du Congo (inédit, 26 pp.).
MWANGO, J., CHILALA, M. & BWEUPE, C. 1999. Analysis of Aquaculture Development in Zambia. — Lusaka, MAFF, 27 pp.
PERCY, D. R. & HISHAMUNDA, N. 2001. Promotion of Sustainable Commercial Aquaculture in Sub-Saharan Africa, Volume 3: Legal, Regulatory and Institutional Framework. — FAO Fisheries Technical Paper 408.
RUKERA TABARO, S., MICHA, J.-C. & DUCARME, C. 2005. Essais d'adaptation de production massive de juvéniles de *Clarias gariepinus* en conditions rurales. — *Tropicultura*, **23** (4): 231-144.

RUKERA TABARO, S., MUTANGA, O., RUGEGE, R. & MICHA, J.-C. 2012. Optimum rabbit density over fish ponds to optimise Nile tilapia production in an integrated rabbit-fish system in Rwanda. — *African Journal of Aquatic Science*, **37** (2): 165-174. http://www.ajol.info/index.php/ajas/article/view/78296

SARNISSA 2013. http://lists.stir.ac.uk/pipermail/sarnissa-french-aquaculture/2010-May/001179.html

SOMA, K., MWANGO, J. & MAZINGALIWA, K. 1999. Analysis of Fish Culture in Zambia. — Lusaka, JICA, 90 pp.

TACON, A. 2004. Use of fish meal and fish oil in Aquaculture, a global perspective. — *Aquatic Resources, Culture and Development*, **1** (1): 3-14.

TACON, A., METIAN, M. & HASAN, M. R. 2009. Feed ingredients and fertilizers for fish farmed aquatic animals. FAO Technical paper 540. — Rome, FAO, 222 pp.

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Biodiversity of Edible Insects of Lower Congo in the Democratic Republic of the Congo

by

Séverin TCHIBOZO*, Paul LATHAM**,
Patricia MERGEN*** & Franck THEETEN***

KEYWORDS. — DRC; Lower Congo; Edible Insects; Host Plants; Dishes.

SUMMARY. — The Democratic Republic of the Congo (DRC) has a wide diversity in terms of forest and agricultural wild food. Several field works to inventory non-wood forest products have been carried out in the Congo Basin, yet researchers can access none or only a few of them. We have studied the edible insects of Lower Congo (Bas-Congo) that have been consumed by man for thousands of years and belong to traditional knowledge. We inventoried forty-eight species between 1984 and 1985 and twenty-two in 2010 that are consumed by rural and urban communities. According to the peasants, they represent an important food source, richer in nutriments than beef and bushmeat. In Bukavu (South Kivu), the market price of one hundred caterpillars is the same as the price of one kilogram of beef meat (Munyuli Bin Mushambanyi 2000). Edible insects could be a source of meat for tomorrow, a solution to fight malnutrition, besides the fact that their breeding produces limited greenhouse gases. The poster shows edible insects collected in Lower Congo, their host plants and some dishes.

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The Status of Indigenous Village Chicken Production in the Democratic Republic of the Congo

by

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KEYWORDS. — Democratic Republic of the Congo; Constraints; Indigenous Chicken; Socio-economic; Smallholder; Village Chicken Production.

SUMMARY. — Local chicken breeds significantly contribute to the world production of meat and eggs and represent 80 % of the world poultry population. However, the majority of these breeds had not been recorded and studied. In the Democratic Republic of the Congo (DRC), poultry keeping is an important livelihood opportunity for the poor. To improve the local poultry sector, many problems must be solved.

The main objectives of this work were to evaluate the chicken production system in the DRC (Kinshasa and Bas-Congo) and its contribution to the food security, to improve the breeders' income and to identify chicken production related constraints.

The results revealed that the traditional production was dominant in the chicken production system, where the local chicken was managed mainly on scavenging with a poor supplementation of grains and household food stuff. The poultry significantly contributed to the livelihoods of poor households: economically as an initial capital, as a protein source and for disposable income and exchange purposes; and socio-culturally for hospitality and exchange of gifts to strengthen social relationships. Limiting factors are: animal diseases, food resource, housing conditions and predators. Thus, the economic and nutritional conditions of households can be improved by developing the local production potential.

In order to reach this objective, special attention should be paid to food quality and management practice in general, including access to veterinary care. The genetic improvement is very important to protect local poultry breeds and increase their productivity whilst respecting the local breeding context.

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Rotenoid Content and *in vitro* Acaricidal Activity of *Tephrosia Vogelii* Leaf Extract on the Tick *Rhipicephalus Appendiculatus*

by

Moïse KASEREKA KALUME*, B. LOSSON**, L. ANGENOT***, M. TITS**, J. N. WAUTERS***, M. FREDERICH*** & C. SAEGERMAN****

KEYWORDS. — *Tephrosia vogelii* (Fabacea); Rotenone; Deguelin; LD50; *Rhipicephalus appendiculatus*.

SUMMARY. — Acaricidal compounds that are currently used in tick control for livestock in the Democratic Republic of the Congo (DRC) are very expensive. Current concern regarding food safety and environmental quality have raised the general public's interest in using alternative (non-synthetic pesticide) pest control methods that are not toxic to the ecosystem. *Tephrosia vogelii* chemotype 1 (C1) white (TVW) and purple (TVP) flowers varieties have this potential. The aim of the present study was to determine the rotenoid contents of leaf extracts of TVW and TVP and to evaluate their *in vitro* acaricidal activity on the tick *Rhipicephalus appendiculatus*, one of the main ectoparasites of cattle in the eastern part of the DRC.

Leaves from TVW and TVP were collected in North Kivu Province (DRC) and were left to dry. The powdered plant material was extracted with 100 ml of 95 % ethanol by percolation technique. Rotenoid content was determined by high-performance liquid chromatography (HPLC).

The ticks *R. appendiculatus* were collected from naturally infected bovines in North Kivu. The viability of the ticks was recorded every twenty-four hours for five days after exposure to increasing doses of leaf extracts.

The comparison of the mortality rates of ticks between treatments was made by means of a test of Welch. The lethal dose 50 (LD50) was determined according to FINNEY (1971).

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Leaves of TVW had a higher content of rotenoids (1.18 %) when compared to TVP (0.67 %). However, the dose-response relationship after five days of treatment showed a similar acaricidal effect with similar LD50 of 0.83 and 0.81 mg/ml for TVW and TVP, respectively.

Although the LD50 of both varieties of *T. vogelii* were similar, the leaves of TVW were shown to contain higher amounts of rotenoid compounds, suggesting that TVW should be used in priority. However, seasonal variations should be analysed before concluding that these differences are significant. Thus, *T. vogelii* leaves (C1) may be used for the control of *R. appendiculatus* in areas where synthetic acaricides are either not available or not affordable. However, *T. vogelii* extract should be sprayed in order to limit the potential risks of ecotoxicity linked to rotenoid compounds.

REFERENCE

FINNEY, D. J. 1971. Probit analysis (3rd Ed.). — Cambridge, Cambridge University Press, 333 pp.

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Epidemiological Follow-up of Bovine Theileriosis to *Theileria Parva* in North Kivu Province, Democratic Republic of the Congo

by

Moïse KASEREKA KALUME*, C. SAEGERMAN** & B. LOSSON***

KEYWORDS. — Epidemiology; Bovine Theileriosis; *Theileria parva*; North Kivu.

SUMMARY. — East Coast fever (ECF) poses a major threat on cattle production in the eastern part of the Democratic Republic of the Congo (DRC), where the activity of the main vector of ECF, the tick *Rhipicephalus appendiculatus*, is very high. Very few studies on ECF are available in the DRC. The present study aims at determining the epidemiological status of the disease and at proposing control methods.

Three studies were conducted in North Kivu. A retrospective survey (2007-2008) carried out among 1,021 veterinarian surgeons allowed the collection of data concerning the epidemiological situation of the three major tick-borne diseases: ECF, anaplasmosis and babesiosis. A cross-sectional study (February-April 2009) was conducted among 29 herds (1,427 cattle heads) raised under a fenced system in two agro-ecological zones at medium (1,000-1,850 m) and high (>1,850 m) altitude: all attached ticks (3,215) were collected by manual extraction on 482 animals; 4,353 ticks were collected by flagging in the pastures. Additionally, the *Theileria parva* seroprevalence was measured by the indirect fluorescence antibody test (IFAT) on 450 blood samples. Thirdly, the dynamics of the transmission of *T. parva* was studied over a period of one year (October 2009 to September 2010) in two cohorts in Butembo: a first cohort of 38 free grazing indigenous cattle and a second cohort of 34 bovine cross-breed grazing under a fenced system. Monthly, *R. appendiculatus* were counted on each animal; animals were examined clinically and blood sampled for an IFAT. Clinical ECF was diagnosed when symptoms of the disease were confirmed by the demonstration of *T. parva* schizonts in lymph node smears. The diagnosis of subclinical ECF was based on isolated seroconversion.

The results of the different studies highlight the risk factors of ECF in North Kivu: climatic and ecological conditions favourable to the vector and low availability of tools to control the disease. Thus, animals must be immunized by the so-called infection and treatment technique. Regular control of ticks is necessary and clinical cases need to be treated.

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Human Health Risk by the Consumption of Metal and POP-Contaminated Fish in the Congo River Basin (CRB)

by

Vera VERHAERT[1], Adrian COVACI[2], Dieudonné MUSIBONO[3], Erik VERHEYEN[4,5], Lieven BERVOETS[1] & Ronny BLUST[1]

KEYWORDS. — Human Health Risk; Persistent Organic Pollutants; Metals; Fish Consumption; Congo River Basin.

SUMMARY. — Fish is an important nutrition source for the subsistence fishing communities of the Congo River Basin (CRB) [1, 2]*. Fish provides dietary proteins and nutrients but fish consumption is also an important pathway of human exposure to metals and persistent organic pollutants (POPs) [3].

Metals (Hg, Pb, Cd) and POPs (PCBs: polychlorinated biphenyls, PBDEs: polybrominated diphenylethers and OCPs: organochlorine pesticdes) can be transferred across trophic levels of the food chain by the processes of bio-accumulation and bio-magnification. The toxic effects of metal and POP pollution are frequently manifested most explicitly at the level of top-predators, including human consumers of contaminated freshwater fish [4]. Metals and POPs have been demonstrated to cause a variety of adverse health effects such as cancer and effects on the immune, reproductive, nervous and endocrine system [5, 6].

To determine the level of contamination in fish of the CRB, different fish species were collected from three tributaries (Lomami, Aruwimi and Itimbiri) and the Congo River itself (in between Kisangani and Bumba). Concentrations of metals (*e.g.*, Hg, Pb, Cd) and POPs (*i.e.*, PCBs, PBDEs, OCPs) in the muscle tissue were determined with ICP-MS and GC-MS, respectively. To assess the human health risk by the consumption of contaminated fish, the muscle concentrations were related to guidelines (ADI, PTWI, MRL) set by the FAO/WHO [3] and ATSDR [7].

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* The numbers in brackets [ ] refer to the references, p. 184.

For example in case of PCBs, a person of 70 kg who consumes more than 70 g/day of fish muscle from the Itimbiri River, exceeds the MRL for PCBs (30 ng/kg body weight/day). The banks of the Itimbiri River are populated with subsistence fishermen who depend largely on fish consumption. In addition, fish is caught, smoked and sold in larger cities. Thus, fish of the Itimbiri River is intensively consumed and this might have implications on the health of the population.

REFERENCES

[1] BENE, C., STEEL, E., LUADIA, B. K. & GORDON, A. 2009. Fish as the "bank in the water" — Evidence from chronic-poor communities in Congo. — *Food Policy*, **54**:108-118.

[2] FAO 2009. Fishery and Aquaculture Country Profiles. Vue générale du secteur des pêches national, Republique Démocratique du Congo, 13 pp.

[3] FAO/WHO 2011. Report of the Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption. — Rome, Food and Agriculture Organization of the United Nations; Geneva, World Health Organization, 50 pp.

[4] DU PREEZ, H. H., HEATH, R. G. M., SANDHAM, L. A. & GENTHE, B. 2003. Methodology for the assessment of human health risks associated with the consumption of chemical contaminated freshwater fish in South Africa. — *Water SA*, **29**: 69-90.

[5] USEPA 2012. Health Effects of PCBs. Last update: 3 April 2012. Online available at: http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/effects.htm

[6] USEPA 2013. Health Effects of Methyl Mercury. Last update: 7 February 2012. Online available at: http://www.epa.gov/hg/effects.htm

[7] ATSDR, Agency for Toxic Substances and Disease Registry 2010. Minimum Risk Levels (MRLs). Online available at: http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls_december_2010.pdf

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Rodent Damage Assessment on Crops (Rice and Maize) in the Region of Kisangani (DRC)

by

Nicaise AMUNDALA DRAZO*, Erik VERHEYEN**,***,
Herwig LEIRS**,**** & Akaibe DUDU*

KEYWORDS. — Rice; Corn; Damage Assessment; DRC.

SUMMARY. — We evaluated pre-harvest damage caused by rodents on crops of maize and rice — among the preferred agricultural crops of farmers in the region of Kisangani (DRC) — in three experimental fields of mixed crops. Each of these study fields was one hectare large and situated in three Communities in the Tshopo District near the city of Kisangani. They were monitored for a period of two years (between March 2006 and June 2008).

We planted and harvested the 07 Nerica rice (*Oriza sativa*) and the Kasai variety of maize (*Zea mays*) twice a year, with the first growing season situated between March and June, and the second growing season between September and January. We planted four seeds of paddy rice and three corn seeds, some in holes 25 cm apart, some in holes 1 m apart. We assessed the damage during the different phenological stages of the crops (planting and emergence, growth, fruiting and seed maturity) by counting the number of corn stalks and rice paddy that were cut down by rodents. To avoid underestimating the damage due to compensatory growth of stems between our last assessment and the harvest, our last damage estimation was done only one week before the crops were harvested.

Our results indicate that the damage in these fields was mainly caused by Greater Cane Rat (*Thryonomys swinderianus* Temminck, 1827) and that the inflicted damage was particularly important during the early stages of crop growth (between 4 and 7 weeks after sowing). That the damage was caused by this rodent species was evident from the fact that crop stems are typically cut down at a height between 7 and 25 cm, much too high above ground level to imply other local rodent species. Finally, this study also indicated that the annual yield loss caused by the Greater Cane Rat approximated 25.7 % for rice and 27.9 % for corn, the equivalent to a total of nearly 2 million US dollars per year for the Tshopo District alone.

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Spatial Variability of Fruit Fly Agricultural Pests (*Diptera: Tephritidae*) in Rural Areas and Tropical Forests of Central Congo

by

Massimiliano VIRGILIO[*], T. BACKELJAU[**,***], R. EMELEME[****], P. BAELO[****], J.-L. JUAKALY[****] & M. DE MEYER[*]

KEYWORDS. — *Tephritidae*; Agricultural Pests; Congo River; Spatial Scales; Human-mediated Disturbance.

SUMMARY. — The dipteran family *Tephritidae* (fruit flies) is widespread and comprises a number of potentially invasive, frugivorous pests causing major agricultural losses worldwide. In Africa, frugivorous tephritid flies put the income of rural small-scale farmers at risk and can reduce the availability of essential dietary components. Most of our current knowledge about African fruit flies originates from studies performed in agricultural areas, while information about the distribution of these species in pristine or moderately disturbed environments is extremely scarce. Therefore, we characterized the spatial distribution of tephritid flies along a 250 km stretch of the Congo River (Democratic Republic of the Congo). Two habitats (tropical forests and small rural villages) were sampled at four locations with three replicate sites for each combination of habitat and location. Sampling with modified McPhail traps baited with four different attractants yielded thirty tephritid species of six genera (*Bactrocera*, *Carpophthoromyia*, *Ceratitis*, *Dacus*, *Perilampsis*, *Trirhithrum*). The three most abundant species were common agricultural pests (*Dacus bivittatus*, *D. punctatifrons*, *Bactrocera invadens*). Sixteen species, most of which of agricultural importance, were only sampled in villages, while five species were only found in forests. *Dacus bivittatus*, *D. punctatifrons* and *Bactrocera invadens* contributed 98.29 % of the overall dissimilarity between forest and village assemblages and showed significant variations in abundance across locations and sites. Accordingly, assemblages differed among locations and sites while they showed significant differences between habitats only in two out of the four locations sampled. Hence, the distribution of fruit flies in central DRC appears mainly related to variations in the environmental features of locations and sites, while anthropogenic disturbance represented by small-scale agriculture and local commerce seems to have only a secondary role.

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Variation in Physico-Chemical Characteristics of Pulp and Oil from Safou (*Dacryodes edulis* (G. Don) H. J. Lam) Fruits: Classification and Relationship with Morphological Traits

by

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KEYWORDS. — Safou; *Dacryodes edulis*; Chemical Characteristics; Morphological Characteristics; Classification; Multivariate Statistics.

SUMMARY. — Safous (*Dacryodes edulis* fruits) picked on 213 safou trees in Franceville, South-East Gabon, were characterized for their chemical and morphological traits. All chemical parameters studied, including moisture, lipid, carbohydrate, protein, ash and fatty acids, showed a high tree-to-tree variation. Fatty acids order in pulp oils allowed to distinguish four profiles, one of them, the so-called Profile I, being by far the most important (recorded on 184 trees, about 86 % of the population). Nevertheless, oil obtained by mixing all pulps showed good physico-chemical properties, suggesting that safou could be a useful raw material for the lipid industry. Safou trees were grouped into three classes according to their morphological traits, while Ascending Hierarchical Clustering (AHC) showed also three classes based on chemical characteristics. Morphological and chemical classes obtained can orient safou producing and oil industries to the major class (2B), which presents mean morphological traits and high lipid content.

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Nutritional Status of the Populations of the Congo Basin: Today and Tomorrow

by

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KEYWORDS. — Rainforest; Congo Basin; Undernutrition; Deforestation; Children; Diet; Food Security; Livelihoods.

SUMMARY. — Africa's forests make up around 20 % of the total global tropical rainforest area and are mainly concentrated in the Congo Basin. The massive Congo Basin rainforest covers an area of over 1.5 million km^2 and is the world's second largest contiguous forest after the Amazon Basin rainforest. Six countries are generally associated with the Congo River rainforest, namely Cameroon, the Central African Republic (CAR), the Republic of Congo, the Democratic Republic of the Congo (DRC), Equatorial Guinea and Gabon, but some authors add Angola. Over 30 million people reside in the Congo River rainforest region, with over 53 % living in rural areas and relying on forest products for their diets and livelihoods. The impact of the forest and this style of living on their food security and nutrition status has not been well documented. However, the countries of the region are among those experiencing high levels of underfive undernutrition, general population insufficient daily caloric intake and a high proportion of households with poor access to food. Thus, despite the quantitatively and qualitatively appreciable contribution of forest products to the diets and livelihoods of the population of these countries, undernutrition remains a public-health problem that must be urgently addressed. However, the importance of the problem varies from one country to another. Population growth and the limited capacity of the forest to sustainably cover the food requirement of the population and the serious consequences to foresee in case of deforestation impose timely implementation of strategies that will qualitatively and quantitatively improve households' access to food. These strategies will also minimize deforestation and maintain a sustainable extraction-to-production ratio of wild food products. Fortunately, the deforestation, although accelerating, is still among the lowest in the world. Efforts to maintain this low level of deforestation while promoting local development should be prioritized by all.

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Brief Presentation of the Congo Basin Forest

Africa's forests make up around 20 % of the total global tropical rainforest area and are mainly concentrated in the Congo Basin (FAO-ITTO 2011). The massive Congo Basin forest, which covers an area of over 1.5 million km^2, is the world's second largest contiguous forest after the Amazon Basin forest (FAO-ITTO 2011, MAYAUX *et al.* 2013, Congo Basin FP 2006). Nine countries — Angola, Cameroon, the Central African Republic (CAR), the Democratic Republic of the Congo (DRC), the Republic of Congo, Burundi, Rwanda, Tanzania and Zambia — have the whole or part of their territory in the Congo River Basin (SINGH *et al.* 1999, BAILEY *et al.* 1992). However, conventionally, only the six countries with extensive rainforest cover are generally associated with the Congo River rainforest, namely Cameroon, the CAR, the Republic of Congo, the DRC, Equatorial Guinea and Gabon (MAYAUX *et al.* 2013, TOLLENS 2010, MEGEVAND 2013). Some authors add Angola, which includes the enclave of Cabinda embedded in the DRC and shares Mayombe rainforest with the DRC and the Republic of Congo (GARNIER-SILLAM & HARRY 1995, IJANG *et al.* 2012). The DRC, with 107,181 million hectares and 60 % of Central Africa's lowland forest cover, contains the largest area of rainforest of the seven countries mentioned (tab. 1) (MAYAUX *et al.* 2013, RIDDER 2007).

A quarter of the total population of the Congo Basin countries (over 30 million people) resides in the rainforest region, with over 53 % living in rural areas and most of whom are relying on forests for their livelihoods (MAYAUX *et al.* 2013, MEGEVAND 2013, NDOYE & TIEGUHONG 2004). This living style and the demographic growth are the principal factors contributing to the deforestation in the Congo Basin (MAYAUX *et al.* 2013, TOLLENS 2010, NDOYE & TIEGUHONG 2004). Although the deforestation rate is still low by any standard (0.16 % per year), the trend can rapidly change if the current population growth estimated at 2.87 % per year is maintained (MAYAUX *et al.* 2013, MEGEVAND 2013). The combination of the deforestation and population growth is likely to further deteriorate the socio-economic conditions of this population relying on the Congo Basin forest for their livelihood (MAYAUX *et al.* 2013). This will be dramatic as all the countries of the Congo Basin have already social and economic indicators typical for developing countries (tab. 1) (TOLLENS 2010). Indeed, based on the Gross Domestic Product (GDP), some of the countries are classified as very poor (DRC and CAR), others as lower middle income (Congo and Cameroun) or middle income (Equatorial Guinea, Angola, Gabon) (TOLLENS 2010).

Table 1
Forest cover and economic characteristics of the Congo Basin countries[1]

Country	Humid rainforest (X 1000 hectares)[2]	Total[3] forest cover (X 1000 hectares)[4]	Population 2008 (X1000)	Population density (/km²)	Gross Domestic Product/capita US$ (2006)[2]
Democratic Republic of Congo	107,181	154,135	64,257	28	130
Gabon	22,416	22,000	1,448	6	5,360
Congo	20,932	22,411	3,615	11	1,370
Cameroon	20,037	19,916	19,088	40	980
Central African Republic	5,833	22,605	4,339	7	370
Equatorial Guinea	2,163	1,626	659	23	8,510
Angola	290	58,480	18,021	14	2,445

[1] *Source*: MAYAUX *et al.* 2013, TOLLENS 2010, International Monetary Fund database.
[2] *Source*: MAYAUX *et al.* 2013.
[3] Total includes humid and dry forest.
[4] *Source*: RIDDER 2007.

Children Nutrition Status in the Congo Basin Countries: Current Situation and Future Prospect

The food security and undernutrition level can be measured using many different indicators, but for this paper we have chosen to use children undernutrition measured by anthropometry [1]*, the Food and Agriculture Organization (FAO) undernutrition index based on the average daily caloric intake and minimum calorie thresholds [2] and the World Food Programme (WFP) food consumption score based on diet diversity and food frequency [3] (JENSEN & MILLER 2010). This choice was made because these are the criteria currently used globally to measure the countries' situation and describe progress towards Millennium Development Goals (MDGs) (UN Economic Commission for Africa 2011).

Data on the food security and the nutrition status of people living in forest region are scarce (BLANEY *et al.* 2009, pp. 1711-1725, pp. 1946-1959). Thus, the impact of the forest on the nutrition status of populations of the forest has not been well documented (BLANEY *et al.* 2009, pp. 1711-1725, pp. 1946-1959). In this section we are presenting the situation using national data for

* The numbers in brackets [ ] refer to the notes, pp. 203-204.

selected Congo Basin countries. The three criteria chosen and described above consistently indicate that unacceptable fractions of populations of countries of the Congo Basin forest are currently experiencing food insecurity and undernutrition. Indeed, the data extracted from the World Health Organization (WHO) global database on child growth and malnutrition we present in figure 1, clearly show that all forms of undernutrition in underfive children are at alarming levels. The levels of stunting, underweight and wasting suggest these forms of undernutrition are public health problems in all the countries as the prevalences are above the set threshold of 20 %, 10 % and 5 % (MEGEVAND 2013). Thus, more than 5 % of the underfive children of these countries are exposed to the immediate consequences of wasting, which include increasing severity of common infant and children diseases and increasing risk of death before reaching the fifth anniversary. Also, more than 20 % of the children are exposed to the long-term consequences of stunting, including reduced productivity, increasing risk of chronic diseases such as diabetes and hypertension. However, it is worth mentioning that the severity of the situation varies from one country to another, with Gabon and Equatorial Guinea being less affected (fig. 1). Also, data from the same WHO global database on child growth and malnutrition and Demographic Health Surveys (DHS) suggest that the prevalence of chronic malnutrition or stunting is reducing overtime in Gabon and Equatorial Guinea and Angola, not in the other countries, which are unfortunately among the most populated of the Congo Gasin (fig. 2). This situation means that, if the current trend is not reversed, the future is not bright for the Congo Basin given the short- and long-term consequences of the continued rampant child undernutrition in many countries of the region (MEGEVAND 2013).

Data based on the FAO index extracted from the FAO statistic database are in concordance with data based on children undernutrition prevalence. They confirm widespread food insecurity in countries of the Congo Basin as the proportion of the country population having daily energy intake below 1,800 kcal is ranging from 15 % to 70 % (fig. 3). This is well above the acceptable < 5 %. Moreover, the situation is worsening, especially in the DRC, where the last available data indicate that over 60 % of the population were not eating enough to meet recommended daily energy intake in 2006 for the DRC (fig. 3). In addition to low calories consumption, data based on the WFP food diversity and frequency score obtained from WFP website demonstrate that only 57 % of the DRC households have acceptable food consumption diversification and frequency and can be considered food secure and at low risk of nutrition deficiencies. This figure is slightly better for the

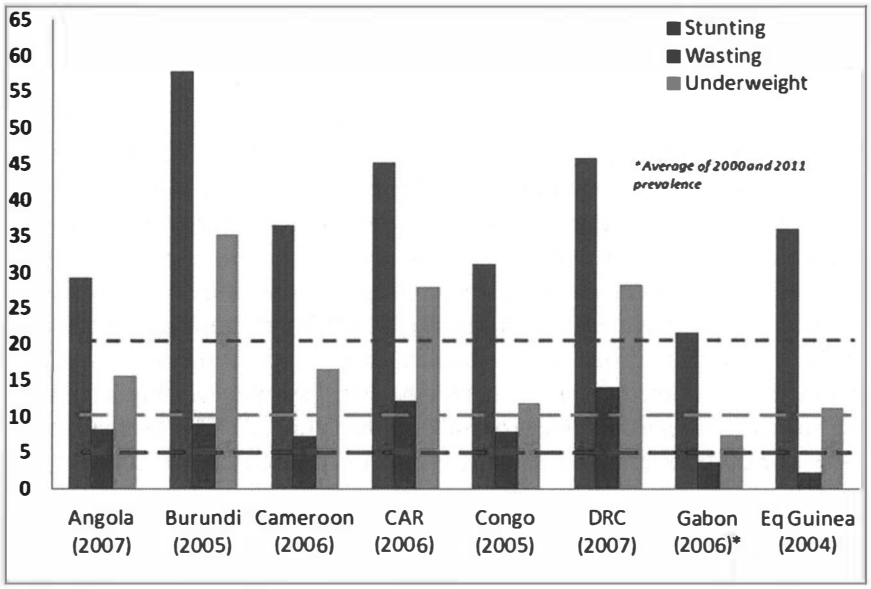

Fig. 1. — Prevalence of stunting, underweight and wasting among underfive children in selected countries of the Congo Basin.

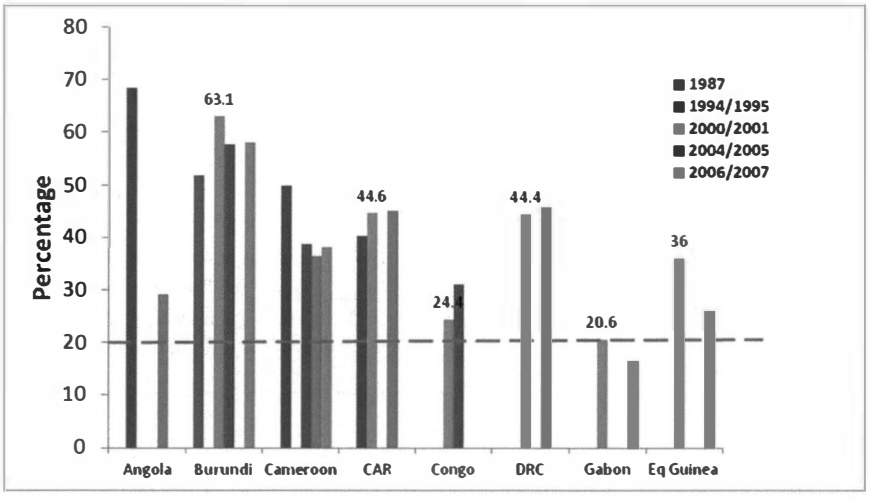

Fig. 2. — Trends in prevalence of stunting from 1987 to 2007 in Congo Basin.

other countries of the region, where 69.8 % (CAR), 74 % (Cameroon) and 92.2 % (Congo) are considered having an acceptable food-security condition. However, in these countries too, a proportion varying from 1.3 % in Congo to 9.0 % in Cameroon has difficulties to access food providing proteins (pulses, milk, meat) and vitamins (fruits). The correlation observed in the DRC between the level of food diversification and frequency and prevalence of stunting (fig. 4) suggests long-term insufficient intake of type-two nutrients (essential amino acids, sulphurs, zinc, magnesium, ...). This is understandable, given the fact that in many of these countries, the agriculture-based auto-subsistence form of economy and production favouring the production of staple food, is predominant (tab. 2). Understandably, the consumption of animal-source food is limited and is far below the 40kg/person/year of meat, fish or eggs and 182 litres/person/year of milk products (tab. 2). The comparison of 1995 and 2005 data suggests that the quality of diet in most Congo Basin countries is not significantly improving (tab. 2).

Table 2
Principal crops and consumption of animal source food[1]

Country	**Meat consumption** (kg/person/year)		**Milk consumption** (kg/person/year)		**Egg consumption** (kg/person/year)		**Important crops ranked according to production tonnage**
	1995	2005	1995	2005	1995	2005	
Democratic Republic of Congo	5.4	4.6	0.9	1.3	0.1	0.1	Cassava, plantains, maize, groundnuts, rice
Gabon	57.0	64.4	26.1	37.5	1.3	1.2	Plantains, cassava, yams, taro, groundnuts
Congo	18.3	21.0	10.1	20.9	0.3	0.8	Cassava, bananas, plantains, groundnuts, yams
Cameroon	12.9	13.5	14.4	13.7	0.7	0.5	Cassava, plantains, taro, bananas, maize
Central African Republic	25.8	31.0	14.2	13.7	0.7	0.5	Cassava, yams, maize, groundnuts, plantains
Equatorial Guinea							Cassava, sweet potato, plantains, bananas, taro

[1] Adapted from TOLLENS 2010.

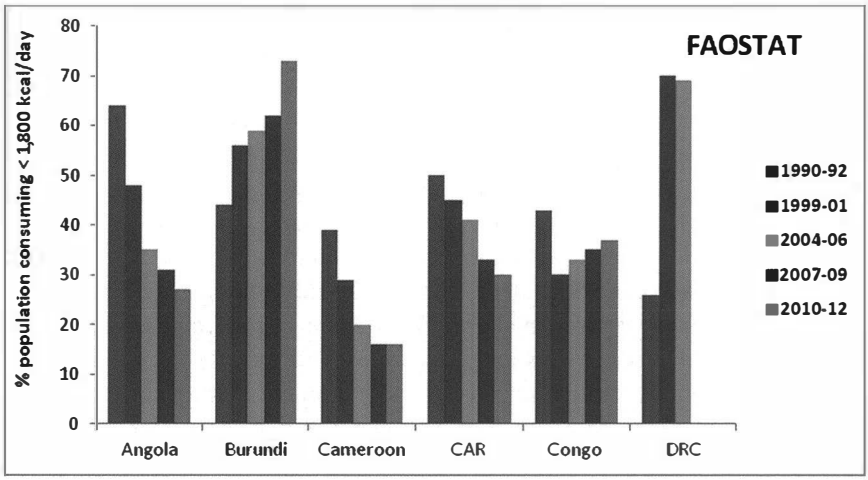

Fig. 3. — Recent trends in calories consumption in selected countries of the Congo Basin.

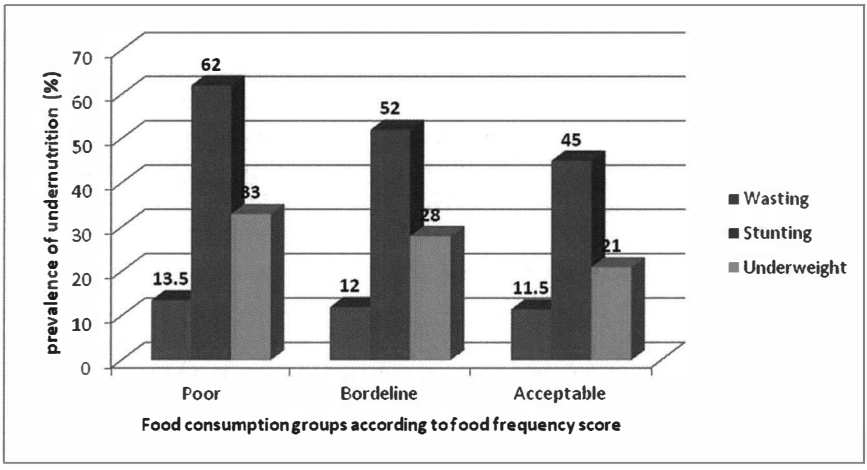

Fig. 4. — Prevalence of stunting, underweight and wasting in the DRC according to food security measured by the WFP food diversity and frequency score (2007-2008 CVFSA).

Current Contribution of the Forest to the Diet in Congo Basin Countries

According to many authors and to the FAO, around one billion people use wild foods in their diet globally (NDOYE & TIEGUHONG 2004, BHARUCHA & PRETTY 2010, MAROYI 2011, SNEYD 2013, ARNOLD *et al.* 2011, BYRON & ARNOLD 1999). However, currently, forest foods rarely make up the majority of items in the diet neither by number nor by volume and seldom provide the staple foods (ARNOLD *et al.* 2011). But wild edible plants, wild fruits and wildlife supplement what is available from other sources, and improve minerals, micronutrients, proteins and fibres intakes of people from developing countries, especially during periods of food shortage (ARNOLD *et al.* 2011). Indeed, in many areas, forest foods play a major role in supplementing staples with essential amino acids and micronutrients (ARNOLD *et al.* 2011).

Congo Basin forests as a natural resource pool provide diet and livelihood to almost around 80 % of millions of people living in the area (NDOYE & TIEGUHONG 2004, SOMORIN *et al.* 2012, SONWA *et al.* 2012, BELE *et al.* 2014, NKEM *et al.* 2008, DEBROUX *et al.* 2007). Indeed, overall 3 % of the DRC population have hunting, gathering or fishing as main source of food (IPC 2012), but this proportion is even higher, ranging between 20 and 40 % for provinces with the highest rainforest cover, namely Maniema, Orientale province and Equateur province (DE MERODE *et al.* 2003). In these provinces, the overall contribution of forest products to diet and livelihood of their inhabitants is certainly more important, especially for rural populations that eat some of the food harvested from the forest and undoubtedly use cash income from the sale of forest products for food purchase especially of staple food (DE MERODE *et al.* 2003, 2004; COAD *et al.* 2010). Confirming this, a study conducted in a northeastern village of the DRC showed that bushmeat, fish and wild plants contribute to 3.1 % (0.04 kg/day), 6.2 % (0.06 kg/day) and 9.6 % (0.11 kg/day) respectively, of the food consumed in the households (DE MERODE *et al.* 2003). This is after the sale of over 90 % of the bushmeat and fish (DE MERODE *et al.* 2003). Another study carried out in the same province of the DRC but in a less remote area reported a much lower contribution of forest products to the diet, especially in cities, as wild edible plants (WEP), together with wildlife, contributed only 2 and 10 % of the total energy intake in cities and rural villages, respectively (TERMOTE *et al.* 2010, pp. 417-427; TERMOTE *et al.* 2010, pp. 173-207).

More interestingly, a study in Gabon has indicated that the use of WEP and wildlife foods improves the quality of diet. The study showed that its use

was also associated with dietary nutrient adequacy in children (over two years of age) and adolescents (BLANEY *et al.* 2009). In fact, forest product consumption positively and significantly impacts on the intake of critical nutrients such us vitamin A, C and B-6 and calcium (TERMOTE *et al.* 2010, pp. 417-427). Similar findings have been reported for people of other forest areas. In the Madagascar forest region, wildlife consumption by a child was associated, when controlling for age and household income, with a mean increase in haemoglobin concentration of 0.69g/dl (GOLDEN *et al.* 2011). It was projected that in that region, removing household access to wildlife will result in a decrease of the haemoglobin level in children of 0.7 g/dl and a nearly 30 % increase in the prevalence of anaemia at the population level from 42 % to 54 % (GOLDEN *et al.* 2011). Pointing in the same direction, a study using 2010 Malawi DHS data also suggested that children living in DHS clusters with a net loss of forest cover during the decade that preceded the survey were 19 % less likely to have a diverse diet, while they were 29 % less likely to consume vitamin A-rich foods when compared to children living in clusters with no net loss of forest cover (JOHNSON *et al.* 2013).

A study carried out in four African countries, including Cameroon, showed that the distance from the city and the wealth rank influence wild food consumption (BRASHARES *et al.* 2011). The study demonstrated that the proportion sold or eaten depends on the wealth and the access to urban market (BRASHARES *et al.* 2011). In the most remote region, bushmeat consumption decreased as the wealth rank increased from 10g/household/day in the lowest wealth deciles to around 4g/household/day in the five deciles of highest wealth rank (BRASHARES *et al.* 2011). In contrast, in the most urbanized region the purchasing power determined the amount of bushmeat consumed and the amount consumed increased as the wealth rank increased from 3g/household/day in the poorest deciles to around 8g/household/day in the three deciles of the wealthiest (BRASHARES *et al.* 2011). These results suggest that in most societies of people from forest areas, wild foods such as bushmeat are actually valued but also that deforestation may have a dramatically and disproportionally impact on the poor as it will affect food consumption of poor people living in rural areas as well as those living in urban areas.

Deforestation Trend and Consequences

The most recent figures on the annual deforestation rate in the Congo Basin rainforest vary according to source and technique used for estimation.

It is reported to be around 0.13 % to 0.26 % per year during the last decade (ERNST *et al.* 2013). This is representing a yearly loss of between 240,000 and 480,000 ha (ERNST *et al.* 2013). This deforestation rate is very low compared to the deforestation in other parts of the world for the same period (0.44 % for the Amazon Basin and 0.41 % for Southeast Asia) (FAO-ITTO 2011, MAYAUX *et al.* 2013, ERNST *et al.* 2013, EVA *et al.* 2012). For other African forests, the figures are 0.35 % for the West Africa forest and 1.08 % for the Madagascar forest (MAYAUX *et al.* 2013). However, this low figure should be interpreted taking into account that the average deforestation rate of the years 2000 to 2010 is the double of the average rate of the years 1990 to 2000 with most of the deforestation happening in some hot spot located in the DRC (ERNST *et al.* 2013). Given that the deforestation in the Congo Basin is driven mainly by increases in population density and subsequent land conversion for small-scale agriculture (MEGEVAND 2013, ERNST *et al.* 2013), the risk of acceleration in the deforestation is important as the population growth rate is important in most of the Congo Basin countries as indicated in a FAO projection obtained from a report by Tollens and presented in table 1 (TOLLENS 2010). At the projected population growth rate, there will be significant decline in available forest edible product *per capita* by 2050 even if the current acceptable extraction to production (E/P) ratio is maintained (FA *et al.* 2003). Indeed, using the example of bushmeat, Fa and Meeuwig showed that in the unlikely scenario of maintenance of the current E/P ratio of 1.07 of bushmeat, the supply per person per day will drop between 2000 and 2050 from 180 to 70 g in Cameroon, from 89 to 40 g in Congo and from around 28 to around 7 g for the other countries of the Congo Basin (FA *et al.* 2003). However, it is predicted that the E/P ratio will increase in all the countries during that period and that the highest increase will be observed in the DRC (4.7) and the lowest in the CAR (2.7) (FA *et al.* 2003). These figures suggest that by 2050 the wild edible resources will have been exhausted in most Congo Basin countries if effective strategies ensuring sustainable harvest are not introduced timely (MEGEVAND 2013, FA *et al.* 2003, WILKIE & CARPENTER 1999, ABERNETHY *et al.* 2013). Thus, it is not surprising that most of the countries of the Congo Basin are classified among those with the lowest probability of reducing the prevalence of underweight or halving the proportion of people suffering from hunger (MDG-1) by 2015 (WHO 2014, STEVENS *et al.* 2012). Indeed, the estimated probability of reducing the underweight prevalence in children below five years of age to less than 2.3, is between 0 and 0.12 only in these countries (STEVENS *et al.* 2012). Thus, in the current scenario, many of the Congo Basin countries are unlikely to make significant progress towards the global target of improving

maternal, infant and young child nutrition by 2025, reducing the number of stunted children by 40 %, reducing the proportion of anaemia among women of productive age by 50 %, reducing low birth-weight rate by 30 %, increasing the rate of exclusive breast feeding during the first six months to at least 50 % and reducing and maintaining the rate of wasting to below 5 % (WHO 2014).

Conclusion

Optimal foetal and child nutrition and development during the life course leads to reduced mortality and morbidity, improved cognitive, motor and socio-emotional development, improved school performance and learning capacity, increased adult stature and reduced risk of obesity and chronic non-communicable diseases and improved work capacity and productivity (Bhutta *et al.* 2008, 2013). To achieve this, adequate provision of essential nutrients from the early stages of life to adulthood, is crucial. Ensuring and maintaining good nutrition status is influenced by several environmental factors and requires the combination of several types of intervention, including nutrition-specific and sensitive interventions and programmes and interventions that improve the socio-economic, political and environmental context. In the Congo Basin forest, edible products are helping millions of people quantitatively and qualitatively complement their diet especially during cyclical (seasonal) shortages and transitory shortages due to natural or man-made external shocks. However, it will be an error to rely only on the forest edible products and forest income as a solution for food shortage in the Congo Basin region. The fight against undernutrition in the region while improving local food production for the people of the Congo Basin should also integrate sustainable management of forest resources among the strategies. The Congo Basin rainforest will be preserved only if the dependency on the forest for food security and livelihoods is reduced. This can only be achieved by diversifying the source of food for the population of the Congo Basin forest, especially the poorest among them.

NOTES

[1] Anthropometric indices that are used to determine the children nutrition status are height-for-age (HFA), weight-for-age (WFA) and weight-for-height (WFH) indices. These indices assess the presence of stunting, underweight and wasting, respectively. For HFA, the height of the child is compared to that of the average

child of the same sex and age of the reference population. For WFA, it is weights that are compared. For WFH, the weight of the child is compared to the average weight of the child of the same height of the reference population.

[2] With this index, the level of undernutrition is defined by the fraction of a population consuming less than 1,800 kcal per day.

[3] The score is calculated using the dietary diversity (defined as the number a food items such as pulses, staple, animal-sources food, fruits, vegetables and sugar) consumed during the previous seven days and the food consumption frequency (defined as the number of days for which each food item was consumed over the previous seven days). The score classifies the households as having poor, borderline or acceptable food security.

REFERENCES

ABERNETHY, K. A., COAD, L., TAYLOR, G., LEE, M. E. & MAISELS, F. 2013. Extent and ecological consequences of hunting in Central African rainforests in the twenty-first century. — *Philosophical Transactions of the Royal Society B: Biological Sciences*, **368** (1625): 20120303.

ARNOLD, M., POWELL, B., SHANLEY, P. & SUNDERLAND, T. C. H. 2011. Editorial: Forests, biodiversity and food security. — *International Forestry Review*, **13** (3): 259-264.

BAILEY, R. C., BAHUCHET, S. & HEWLETT, B. 1992. Development in the Central African Rainforest: concern for forest peoples. — Conservation of west and Central African rainforests, pp. 202-211.

BELE, M. Y., SONWA, D. J. & TIANI, A. M. 2014. Adapting the Congo Basin forests management to climate change: Linkages among biodiversity, forest loss, and human well-being. — *Forest Policy and Economics*, **50**: 1-10.

BHARUCHA, Z. & PRETTY, J. 2010. The roles and values of wild foods in agricultural systems. — *Philosophical Transactions of the Royal Society B: Biological Sciences*, **365** (1554): 2913-2926.

BHUTTA, Z. A., AHMED, T., BLACK, R. E., COUSENS, S., DEWEY, K., GIUGLIANI, E. *et al.* 2008. What works? Interventions for maternal and child undernutrition and survival. — *The Lancet*, **371** (9610): 417-440.

BHUTTA, Z. A., DAS, J. K., RIZVI, A., GAFFEY, M. F., WALKER, N., HORTON, S. *et al.* 2013. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? — *The Lancet*, **382** (9890): 452-477.

BLANEY, S., BEAUDRY, M. & LATHAM, M. 2009. Contribution of natural resources to nutritional status in a protected area of Gabon. — *Food & Nutrition Bulletin*, **30** (1): 49-62.

BLANEY, S., BEAUDRY, M. & LATHAM, M. 2009. Determinants of undernutrition in rural communities of a protected area in Gabon. — *Public health nutrition*, **12** (10): 1711-1725.

BLANEY, S., BEAUDRY, M., LATHAM, M. & THIBAULT, M. 2009. Nutritional status and dietary adequacy in rural communities of a protected area in Gabon. — *Public health nutrition*, **12** (10): 1946-1959.

BRASHARES, J. S., GOLDEN, C. D., WEINBAUM, K. Z., BARRETT, C. B. & OKELLO, G. V. 2011. Economic and geographic drivers of wildlife consumption in rural Africa. — *Proceedings of the National Academy of Sciences*, **108** (34): 13931-13936.

BYRON, N. & ARNOLD, M. 1999. What futures for the people of the tropical forests? — *World development*, **27** (5): 789-805.

COAD, L., ABERNETHY, K., BALMFORD, A., MANICA, A., AIREY, L. & MILNER-GEGULLAND, E. J. 2010. Distribution and use of income from bushmeat in a rural village, central Gabon. — *Conservation Biology*, **24** (6): 1510-1518.

Congo Basin FP 2006. The Forests of the Congo Basin: State of the Forest. — Washington, CBFP, 255 pp.

DEBROUX, L., TOPA, G., KAIMOWITZ, D., KARSENTY, A., HART, T., ABDON, A. *et al.* 2007. Forests in post-conflict Democratic Republic of Congo: Analysis of a priority agenda. — *Selected Books*, **1**. — Jakarta, Center for International Forestry Research (CIFOR), 82 pp.

DE MERODE, E., HOMEWOOD, K. & COWLISHAW, G. 2003. Wild resources and livelihoods of poor households in Democratic Republic of Congo. — *ODI Wildlife Policy Briefing*, **1** (1): 1-4.

DE MERODE, E., HOMEWOOD, K. & COWLISHAW, G. 2004. The value of bushmeat and other wild foods to rural households living in extreme poverty in Democratic Republic of Congo. — *Biological conservation*, **118** (5): 573-581.

ERNST, C., MAYAUX, P., VERHEGGHEN, A., BODART, C., CHRISTOPHE, M. & DEFOURNY, P. 2013. National forest cover change in Congo Basin: deforestation, reforestation, degradation and regeneration for the years 1990, 2000 and 2005. — *Global change biology*, **19** (4): 1173-1187.

EVA, H. D., ACHARD, F., BEUCHLE, R., DE MIRANDA, E., CARBONI, S., SELIGER, R. *et al.* 2012. Forest cover changes in tropical South and Central America from 1990 to 2005 and related carbon emissions and removals. — *Remote Sensing*, **4** (5): 1369-1391.

FA, J. .E, CURRIE, D. & MEEUWIG, J. 2003. Bushmeat and food security in the Congo Basin: linkages between wildlife and people's future. — *Environmental Conservation*, **30** (01): 71-78.

FAO-ITTO 2011. The state of forest in the Amazon basin, Congo basin and Southeast Asia. — Rome, FAO, 80 pp.

GARNIER-SILLAM, E. & HARRY, M. 1995. Distribution of humic compounds in mounds of some soil-feeding termite species of tropical rainforests: its influence on soil structure stability. — *Insectes sociaux*, **42** (2): 167-185.

GOLDEN, C. D., FERNALD, L. C., BRASHARES, J. S., RASOLOFONIAINA, B. R. & KREMEN, C. 2011. Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. — *Proceedings of the National Academy of Sciences*, **108** (49): 19653-19656.

IJANG, T. P., CLETO, N., EWANE, N. W., CHICAIA, A. & TAMAR, R. T. 2012. Transboundary Dialogue and Cooperation: First Lessons from Igniting Negotiations on Joint Management of the Mayombe Forest in the Congo Basin. — *International Journal of Agriculture and Forestry*, **2** (3): 121-131.

IPC 2012. Rapport du 8ème cycle d'analyse du Cadre Intégré de Classification de la Sécurité Alimentaire. — Kinshasa, Ministère de l'Agriculture, Pêche, Elevage et Développement rural, 31 pp.

JENSEN, R. T. & MILLER, N. H. 2010. A revealed preference approach to measuring hunger and undernutrition. — *National Bureau of Economic Research*. — Cambridge, National Bureau of Economic Research, Working Paper Series, **16555**, 25 pp.

JOHNSON, K. B., JACOB, A. & BROWN, E. 2013. Forest cover associated with improved child health and nutrition: evidence from the Malawi Demographic and Health Survey and satellite data. — *Global Health: Science and Practice*, **1** (2): 237-248.

MAROYI, A. 2011. The gathering and consumption of wild edible plants in Nhema communal area, Midlands province, Zimbabwe. — *Ecology of food and nutrition*, **50** (6): 506-525.

MAYAUX, P., PEKEL, J. F., DESCLEE, B., DONNAY, F., LUPI, A. & ACHARD, F. *et al.* 2013. State and evolution of the African rainforests between 1990 and 2010. — *Philosophical Transactions of the Royal Society B: Biological Sciences*, **368** (1625): 20120300.

MEGEVAND, C. 2013. Deforestation trends in the Congo Basin: reconciling economic growth and forest protection: — Washington, DC. The Worldbank, 158 pp.

NDOYE, O. & TIEGUHONG, J. C. 2004. Forest resources and rural livelihoods: the conflict between timber and non-timber forest products in the Congo Basin. — *Scandinavian Journal of Forest Research*, **19** (S4): 36-44.

NKEM, J., IDINOBA, M. & SENDASHOGA, C. 2008. Forests for climate change adaptation in the Congo basin: responding to an urgent need with sustainable practices. — Jakarta, CIFOR, Environmental Services Briefs, **2**, 6 pp.

RIDDER, R. M. 2007. Global forest resources assessment 2010: options and recommendations for a global remote sensing survey of forests. — *FAO For Resour Assess Programme Work Pap*, **141**. Rome, FAO, 56 pp.

SINGH, A., DIEYE, A. & FINCO, M. 1999. Assessing environmental conditions of major river basins in Africa as surrogates for watershed health. — *Ecosystem Health*, **5** (4): 265-274.

SNEYD, L. Q. 2013. Wild Food, Prices, Diets and Development: Sustainability and Food Security in Urban Cameroon. — *Sustainability*, **5** (11): 4728-4759.

SOMORIN, O. A., BROWN, H., VISSEREN-HAMAKERS, I. J., SONWA, D. J., ARTS, B. & NKEM, J. 2012. The Congo Basin forests in a changing climate: policy discourses on adaptation and mitigation (REDD+). — *Global Environmental Change*, **22** (1): 288-298.

SONWA, D. J., NKEM, J. N., IDINOBA, M. E., BELE, M. Y. & JUM, C. 2012. Building regional priorities in forests for development and adaptation to climate change in the Congo Basin. — *Mitigation and Adaptation Strategies for Global Change*, **17** (4): 441-450.

STEVENS, G. A., FINUCANE, M. M., PACIOREK, C. J., FLAXMAN, S. R., WHITE, R. A., DONNER, A. J. *et al.* 2012. Trends in mild, moderate and severe stunting and underweight, and progress towards MDG 1 in 141 developing countries: a systematic analysis of population representative data. — *The Lancet*, **380** (9844): 824-834.

TERMOTE, C., MEYI, M. B., NDJANGO, J. B., VAN DAMME, P., DJAILO, B. D., BURGT, X. *et al.* 2010. Use and socio-economic importance of wild edible plants in tropical rainforest around Kisangani, District Tshopo, DR Congo. — In: Systematics and Conservation of African Plants: proceedings of the 18th AETFAT Congress. Chicago, University of Chicago Press, pp. 417-427.

TERMOTE, C., VAN DAMME, P. & DHED'A DJAILO, B. T. 2010. Eating from the wild: Turumbu indigenous knowledge on noncultivated edible plants, Tshopo District, DR Congo. — *Ecology of food and nutrition*, **49** (3): 173-207.

TOLLENS, E. 2010. Potential Impacts of Agriculture Development on the Forest Cover in the Congo Basin. — Washington, DC, The World Bank, 51 pp.

United Nations Economic Commission for Africa, Union A. *Assessing Progress in Africa Toward the Millennium Development Goals: MDG Report 2011*: Economic Commission for Africa; 2011.

WILKIE, D. S. & CARPENTER, J. F. 1999. Bushmeat hunting in the Congo Basin: an assessment of impacts and options for mitigation. — *Biodiversity & Conservation*, **8** (7): 927-955.

World Health Organization 2014. Comprehensive implementation plan on maternal, infant and young child nutrition. — Geneva, WHO, Press, 22 pp.

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Persisting High Level of Child Malnutrition associated with Anemia but Low Malaria Infection in a Rural Community of the South Kivu Province, in the Eastern Part of the DR Congo

by

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KEYWORDS. — Malnutrition; Anemia; Malaria; Children under 5; Rural DR Congo.

SUMMARY. — A follow-up of the prevalence of child malnutrition in a population is necessary to assess the effect of public health interventions and of other measures to improve the living conditions, or to evaluate the aggravating effect of socio-economic and political instabilities such as war conflicts. This survey was conducted to assess the prevalence of child malnutrition and its association with other nutriment deficiencies or with malaria in a rural population in a post-conflict context.

Data were obtained from nine hundred children randomly selected in a community cluster survey in the health zone of Miti-Murhesa in April 2013. Demographic information and physical parameters were recorded, and blood samples were collected for biochemical and parasitological analysis. Anemia was defined as hemoglobin concentration <11 g/dl, malaria as thick blood smear positive for plasmodium. Underweight, stunting and acute malnutrition were defined as Z-scores of <-2 for weight for age, height for age and weight for height, respectively, acute malnutrition also by the presence of bilateral pitting edema.

In this sample the sex ratio was 1.03 and the median of age (P25-P75) was 29.4 (12-45) months. Underweight was present in 37.8 %, stunting in 66 % and global acute malnutrition in 8.4 %. Edema was present in 1.6 %. These results suggest the persistence of a chronic malnutrition status. The mean (± SEM) hemoglobin concentration was 115 ± 0.45 g/l and we noted a high prevalence of anemia (28.7 %; n = 840). The mean albumin concentration was 34 ± 0.45 g/l (54.4 % under 35.0 g/l). Malaria infection was present in only 1.03 % (n = 878) and C-reactive protein was increased in 10.2 % (n = 869) of the children.

This study documents that malnutrition remains highly prevalent in the rural context in the South Kivu Province and suggests that the condition is associated with anemia probably caused by iron deficiency. In our study, malaria is not associated with anemia as also proposed by previous studies.

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Reducing Malnutrition in Urban Areas in Sub-Saharan Africa: a Model for identifying Cost-Effective and Sustainable Value Chain Interventions

by

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KEYWORDS. — Malnutrition; Urbanization; Diet Diversity; Value Chain; Women.

SUMMARY. — The urban population in sub-Saharan Africa (SSA) nearly doubled from 146 million to 346 million during the last twenty years, of whom more than 60 % live in slums. Progress in decreasing undernutrition in SSA is slow, also in urban areas. Nearly 30 % of the population is chronically undernourished. At the same time, obesity and overweight amongst urban poor women and pre-school children is rapidly increasing due to, among others, an unfavourable shift in consumption patterns (more fat and sugar, less polysaccharides and fibre). Improving access to nutritious food is key in making a shift towards healthier diets.

The Royal Tropical Institute (KIT), in close collaboration with Bondo University College (BUC), conducted research in slum settlements in Kisumu, Kenya, in November 2012 aimed at designing a model for gender aware, cost-effective and sustainable strategies to better match demand (addressing needs) for and supply of nutritious food in urban areas of pregnant and lactating women with children under two.

Data on food habits, food consumption and socio-economic characteristics were collected from a representative sample of 295 women of reproductive age and children under two. Nearly half of the children and a quarter of the women consumed a diet of poor quality, lacking vitamins and minerals as measured through individual diet diversity scores. Maternal diet diversity was found to be a reliable predictor of child diet diversity. Higher diet diversity was significantly correlated to a higher *per capita* total expenditure, food expenditure and level of education as well as having electricity, a separate place for cooking and an own *shamba*. Enough and sufficiently varied nutritious food was available at the local markets in Kisumu, but affordability in the off-season was a problem, because the cost of a daily food basket — both a nutritiously insufficient and a nutritiously well-balanced menu — is about 70 % higher than in the peak season and out of reach of the poor. Households were found

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to cope by eating less varied, cheaper substitutes and smaller portions because they couldn't afford to spend more on food.

We used a *nutritious food selection matrix* and a *supply chain selection matrix*, to select food products that could potentially be looked into for value chain development options. Both matrixes were developed during the research. Supply chains of selected commodities were mapped and analysed with a view to identify potentially added value to (parts of) the chain. Results indicate that mangoes, traditional green leafy vegetables, amaranth, groundnuts and edible insects could have high potential, particularly if the focus would be on increased availability at prices affordable to the pregnant and lactating women and their small children in the off-season. The identified value chain intervention strategies serving this purpose were: (*i*) increasing efficiency in chain operation, for example through the establishment of preferred supplier relations to target groups and collective purchase of larger quantities (through CBOs) for amaranth; (*ii*) processing perishable foods to increase shelf life and periods of availability for groundnut, mango and green leafy vegetables; (*iii*) focusing on the commercial production of "wild" foods assuring year round supply for edible insects and (*iv*) increasing voice of women in the household and the community and linking women as consumers and producers (linking urban and rural areas) where possible.

Discussions with potential stakeholders interested in public-private partnerships or already involved in activities which can be built upon are expected to result in business propositions for the implementation of one or more interventions before June 2013.