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The Elephant in the Forest: Population Increase and its Effect on Deforestation

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Abstract

The principal cause of global warming is the burning of fossil fuels, which adds about 9.3 billion tonnes of carbon ($34.2x10^9$ tCO_2) to the atmosphere each year. However, deforestation adds about another 1.4 billion tonnes of carbon ($5.1x10^9$ tCO_2) each year. The principal driver of deforestation is the increase in population, mainly in poor tropical countries, and to a lesser extent the expansion of commercial agriculture. If nothing is done to increase agricultural (and forestry) productivity and temper population increase, then deforestation will increase and so will GHGs. Various proposals are made to increase agricultural and silvicultural productivity, capture GHG through tree planting etc. and tempering population growth. Such steps could reverse deforestation. Trees and their products could play a positive role in meeting the Paris Accord Target to control GHG emissions, improve rural income and lead to truly sustainable development.

Keywords: Deforestation; Population increase; Agricultural/silviculture productivity; Tree planting; GHG; Carbon capture and storage (CCS)

Introduction

The principal cause of the increase in greenhouse gases (GHG) is the burning and/or use of fossil fuels. These add about 9.3 billion t of carbon (34.2 billion tCO_2) to the atmosphere each year, but land use changes also contribute another 1.4 billion t. C the GHG total [1].

There was little if any talk at the 2017 Bonn meeting on global warming [2] nor at the December 2018 meeting in Katowice (Poland) [3] about one of the causes of the increase in atmospheric carbon dioxide (CO_2), namely deforestation. While the Polish President declared a 'forests for climate policy', highlighting the important role of forests in solving the climate problem, a resolution welcoming the IPCC 1.5°C report was objected to by four countries, namely USA, Saudi Arabia, Russia and Kuwait, who wanted the report only to be 'noted' not 'welcomed'. Thus, this resolution was postponed to the next Subsidiary Body for Scientific and Technological Advice (SBSTA) to be held in Bonn in June 2019 [4]. According to the latest (December 2018) Climate Action Tracker [5], the increase in temperature is already 1°C above pre-industrial levels and current national policies will result in a 3.3°C warming by 2100 (range 2.5 to 4.4°C). Even the optimistic scenario forecasts 3.0°C warming by 2100

(range 2.4 to 3.2°C). http//climateactiontracker.org. Therefore, there is much to be done to promote the 'Sustainable Development Goals' (SDG) and promoting vigorous reforestation and timber use and population control must be given high priority.

The latest Food and Agricultural Organization's State of the World's Forests [6] and Global Forest Resource Assessment [7], estimate that about 1.4 billion (10^9) tonnes of carbon ($5.1x10^9$ tCO_2) (range 1.1 to 1.6 10^9 tC) are added each year to the atmosphere through deforestation. This is likely to continue due to population pressure and increase in wealth: this could increase, unless steps are taken to decrease deforestation, especially in tropical countries. The principal causes of deforestation are population increase (for subsistence agriculture) and the increased demand for arable and pastoral land for commercial crops such as soy beans, palm oil, coffee and cattle feed [8]: this is what I term '**the elephant in the forest**'.

Urbanization and infrastructure development also contribute somewhat to land use change, but very little from the use of forest resources: the latter may cause some forest degradation, but rarely deforestation: this only occurs when there is a land use change, for 'nature abhors a vacuum'.

Population statistics: In 2015, the population of the world was estimated to be 7,349 million and by mid-2019 is due to reach 7,678 million. It is forecast to grow to 9,725 million by 2050 and to over 11 billion by 2100 [9]. Table 1 gives the population protections for specific years for the world and selected regions, plus the total for less developed countries (LDC). The LDC total is less than the sum for Africa, Asia and Latin America and the Caribbean to account for countries not considered to be LDCs.

As people and countries increase their wealth, the rate of population increase declines; this is especially true for China and to a lesser extent India – the two most populous countries. However, in many developing countries and regions, because of the bulk of the population is or will be in the reproductive stage of life, the rate of increase only declines slightly. Thus, the population of in Sub-Saharan Africa (SSA) is forecast to increase by over 300% between 2015 and 2100 if little is done to temper this increase. This may have a profound effect on the rate of deforestation in SSA. Also, in LDCs excluding China, the population may nearly double between 2015 and 2100! How will this affect deforestation?

Year	2015	2020	2030	2050	2100	2015-2100 % incr.
World	*7,349*	*7,758*	*8,501*	*9,725*	*11,213*	*3,864 53%*
Africa	1,186	1,340	1,679	2,476	4,387	3,201 270%
Sub-S Africa	962	1,096	1,397	2,123	3,935	2,973 309%
Asia	4,393	4,598	4,923	5,267	4,887	494 11%
China	1,376	1,403	1,416	1,348	1,004	- 372 - 27%
Asia excl. China	3,017	3,195	3,507	3,819	3,883	866 29%
L.A.&C	634	667	721	784	721	87 14%
LDC	6,098	6,492	7,217	8,439	9,936	3,782 63%
LDC excl. China	4,722	5,089	5,801	7,091	8,932	4,154 89%

Table 1: Population Projections for the World and Regions. Units million.
Note. Sub-S Africa = Sub Saharan Africa (SSA). L.A.&C = Latin America and the Caribbean. LDC = Less developed countries. The total for LDCs is slightly less than the sum for Africa, Asia and L.A.&C to account for countries not considered as LDCs. % incr. = percentage increase in population from 2015 to 2100. excl. = excluding.
Source. Population Pyramid 2018 [9].

Deforestation Effect of Population Increase

According to FAO statistics [6,7], for the period 2010-2015, the deforestation rate was 7.6 million ha per year, of which natural forests declined by an estimated 6.5 million ha/yr. The bulk of the decline was in tropical areas namely SSA (3.1 million ha/yr.), LA&C (2.2 million ha/yr.) and Asia excluding China (1.0 million ha/yr.). The decline in other areas was 0.2 million ha/yr. Of course, there were gains in forest areas - an estimated 3.48 million ha/yr., notably in China (+1.54 million ha/yr.) - but it will take many years for these gains to offset the carbon loss from the cleared natural forests and woodlands.

In SSA, two-thirds of forest loss was due to subsistence agriculture, whereas in LA&C, 70% of the loss was due to commercial agribusiness - clearing land for soy bean,

palm oil and cattle ranching etc. Between 2015 and 2100, the loss of natural forest and woodland could range from 500 to 800 million ha (5.9 to 9.4 million ha per year), of which an estimated 350 to 520 million ha will be due to the subsistence sector. An estimated 66% of the loss will be in SSA, 30% in Asia and 4% in LA&C[1] [1]. If these estimates are anything near the truth, then the annual emissions of CO_2 from deforestation will be in the region of 3.2 – 5.2 billion tonnes adding to GHG! This will profoundly influence global warming and negatively affect the goal of keeping the global temperature increase below 2^0C from pre-industrial levels – as per the Paris Climate Accord, ratified in November 2016 and action taken at the UN Convention on Climate Change [2]. The aspirational goal from COP24 is keeping the increase in temperature to 1.5^0C above the pre-industrial level [3]. But, according to the latest results from the Carbon Action Tracker [5], most countries are nowhere even near the 2^0C target, let alone the 1.5^0C aspirational figure. Clearly there have to be concerted efforts from scientists, concerned industrialists, the private sector, non-government organizations (NGOs), councils and individual people, especially young people, to put considerable pressure on governments and international bodies to take realistic and immediate action on the proposals from COP 23 & 24. Otherwise, humanity may be in serious jeopardy.

Necessary and Urgent Steps to Meet the Climate Goals

What steps are necessary to reverse this trend and could trees help to meet the goals of the Paris Climate Accord by helping reduce GHGs? Governments have to be much more serious in promoting the sustainable development goals (SDG) and reducing fossil fuel use: this could be done through (increased) carbon taxation, reducing or elimination subsidies on fossil fuels, promoting renewable energy, improving end use efficiency, etc. All these measures have been discussed in detail in COP 23 & 24 etc. and will not be described further here. What will be elaborated is ways to promote carbon sequestration through biomass and to reduce, if not reverse, deforestation. The solutions are several - such as increasing agricultural and silvicultural productivity, reclaiming abandoned and/or degraded lands, stabilizing shifting cultivation, protecting water sources, vesting forest resources in people at the local level and paying them for protection, improving intermediate and end-use efficiencies of wood products, decreasing (food) waste, altering eating habits away from animal proteins, improving infrastructure and education and tempering population increase, especially through empowering women.

Increasing Agricultural Productivity

While at COP 24, the Polish President declared *'a Forest for Climate Policy'* promoting tree planting and management, but of equal importance should have been *'a Farm for Climate Policy'* especially geared to the subsistence sector in LDCs. The main causes of deforestation are clearing land for subsistence agriculture, including shifting cultivation, due to population pressure and the increased demand for cash crops, not harvesting wood as is often cited [10]. Can this clearing be slowed down and eventually reversed? Can agricultural productivity increase by at least the rate of population increase?

The usual methods to increase agricultural productivity are: applying increased amounts of artificial fertilizers, which are produced using fossil fuels; crop and animal breeding, including genetically modified crops; applying pesticides and herbicides; plastic sheets over salad and soft fruit crops and hydroponics etc. It is said that such measures will supply enough food to satisfy the increased demand brought about by population increase and increased wealth [11].

Another intervention is planting shelterbelts to reduce evapo-transpiration of cash crops to increase yields. These are promoted in several countries from China to Egypt. However, there are additional effective ways to increase productivity using 'natural' methods more suited to subsistence farmers. These include: zero tilling, applying slurry from (cheap) biogas plants, manure management and adding lime to the soil. Again, intercropping with nitrogen-fixing species (including trees) can at least stabilize agricultural productivity, if not improve it: this is commonly known as agro-forestry [12]. Pasture land could be planted with nitrogen-fixing tree species to provide fodder and shelter for animals. There are many existing nitrogen fixing trees (e.g. *Acacia sp.*) on such lands and increasing their presence should be encouraged.

[1] These are ball park estimates based on some increase in agricultural productivity and the rate of urbanization in LDC's. Many LDCs will be importing food, especially to feed the urban population. However, the quantity of suitable forest and woodland will decline, and more and more less productive forest cover will be converted to temporary or permanent crop land and pasture. The 'shifting cultivation' cycle under crops will decrease, causing an increase clearing of forest etc. Thus, the above estimates may be low.

Nitrogen-fixing tree species can be used to intercrop in place of shifting cultivation and to eliminate the invasive grass species *Imperata cylindrical* [13]. Brassicas (cabbage etc.) and beans planted side by side can deter the black bean aphid (*Aphis fabae*) from attacking the cabbage. Another intervention was applied to maize in East Africa. Scientists from Rothamstead agricultural research facility (U.K.) found that planting napier grass (*Pennisetum purpureum*) round the edges of maize fields and intercropping the maize with molasses grass (*Melinis minutiflora*), deterred stem borer moths (*Busseola fusca* and *Cholo partellus*). These grasses also attracted parasitic wasps that prey on the moths. Not only were maize (and sorghum) yields increase, but the two grasses are edible fodder for cattle, which meant that farmers could increase their animal stock and provide more milk and dung to fertilise the fields [14]. The grasses also increase the amount of carbon stored in their roots and the soil. Again, one of the curses of poor farmers on poor land in Africa (and elsewhere) is witchweed (*Striga asiatica*) [15], which parasitizes the roots of cereal crops and kills them. The striga seeds can lay dormant for many years and are difficult to control. The same scientists found that a tree legume known as silverleaf (*Desmodium uncinatum)*, if intercropped with maize, resulted in no striga invasion although adjacent maize fields without silverleaf were nearly devastated by it. This more than doubled the yield of maize and the silverleaf provides cattle fodder and stick wood [14]. These are but some examples of the symbiotic relationship between plants that can be easily adapted by farmers, especially subsistence ones, to increase their plant and animal yields.

One of the problems of global warming is that increased temperatures, especially at night, may inhibit the flowers of cereal crops from setting. Rice is the chief crop in many parts of the world, especially in Asia. Scientists at the International Rice Research Institute (IRRI) in the Philippines have a breeding programme to develop rice strains that can tolerate increased night-time temperatures without affecting rice yields, (personal visit). This is but one example of a necessary response to the negative effects of global warming.

Shifting cultivation is a method whereby farmers can grow crops for two or three years on cleared forest areas, before the crop yields are too low for sustenance. The farmers then move to new forest areas and repeat the process, allowing former cleared lands to recover for about 20 years before the cycle is repeated. However, because of increase population pressures, the recovery cycle in many cases is shortened and the cropping time is also curtailed, resulting in lower sustained crop yields and shorter recovery time. Inter-planting nitrogen-fixing crops, especially tree species, can stabilize agricultural productivity and provide animal browse and/or mulch to the soil, as well as stick wood. Also, wood ash is a good fertilizer, being relatively rich in K (potassium), a critical ingredient to maintain soil fertility along with N (nitrogen) and P (phosphorous). Again, applying lime (CaOH) to acid soils improves the availability of P to plants.

Thus nitrogen-fixing plants, especially trees, can stabilise if not increase crop production and increase the carbon store in wood and soils [16]. A book that should be made available to all agricultural and forestry departments in the tropics is *Tropical Legumes: Resources for the Future*, published by US National Academy of Sciences [17].

Photochemists and photobiologists are actively searching for systems which will split water using solar energy. The advantage of these artificial systems over natural photosynthesis is that they might be optimised for natural photosynthetic efficiency [18]. Another intervention that scientists are working on is making cash crops such as maize and rice fix nitrogen. Hopefully such interventions will be commercial in the not too distant future.

Increasing Silviculture Productivity

Besides increasing agricultural productivity at a rate hopefully similar to that of population increase, it is important to increase the productivity of trees, especially nitrogen-fixing species, through breeding, cloning and selecting species that will stand climate change. Such 'superior' species can and should be used to improve carbon storage to help counter CO_2 emissions from fossil fuels.

There are considerable areas of farmland, both rainfed and irrigated, that have been abandoned due to land exhaustion, falling yields, salination and invasion by weeds, pest and diseases such as witchweed (*Striga asiatica*), congon grass (*Imperata cylindrica*), black bean aphids, stem borer moth etc [15]. Top priority should be given to the reclamation of such abandoned areas and to reducing pests and diseases. These areas are candidates for tree plantations and agro-forestry, but some reclamation costs may be high. Generally, however, tree plantations are a cheaper alternative for 'Carbon Capture and Storage' (CCS), than CCS from CO_2 emissions from electric power plants with storage underground or under the sea. What is more, the annual yield from such

plantations may be used for wood products including fuelwood in place of fossil fuels, thus reducing the demand for fossil fuels and the increased CO_2 emissions from them! From 2016 to 2050 about 420 10^9 tC will be added to the atmosphere from the burning of fossil fuels [19]. Ten percent of this, namely 42 10^9 tC could be captured say by 2050 in trees and forest soils (CCS). The area of land required for such an intervention, assuming 67% is in the tropics and 33% in temperate areas, would be between 109 million ha (optimistic assumption) at a cost of about $272 billion ($1.7 per tCO_2) and 330 million ha (pessimistic assumption) at a cost of $1,243 billion, ($7.7 per tCO_2). If the land had to be paid for, then this would increase the CCS price by between $5 and $16 per tCO_2. These costs should be compared to the CCS from a power plant, which would cost in the region of $70 per tCO_2 [20]. In addition, there is the bonus of the annual yield from such plantations, which ranges from 22t/ha of above-ground wood in tropical areas to 11t/ha in temperate areas. (Openshaw 2015)[2] [21].

There are many tree species that can be used to reclaim land, from low to high rainfall areas and from saline to calciferous soils. The US National Academy of Sciences [17] lists tree and other legumes that can be used to restore lands from deserts to tropical highlands. For example, *Prosopis spp.,* including mesquite, can be used to reclaim dry areas, but the total carbon accumulation may only be in the range of 3 to 5 tC/ha/yr. Mesquite is sometimes regarded as a weed species, because animals, especially ruminants, eat the leaves and the seed pods. However, they cannot digest the seed, which is then passed out with the dung. This generally regenerates and spreads. But if the seed pods are collected and milled, thus destroying the seed, the resulting product can be (and is) sold as an excellent animal feed. All legumes, especially tropical tree legumes, have a critical role to play in land reclamation and improving agricultural productivity. Other useful NAS books are: *Firewood Crops* [22] and Firewood Crops, Volume 2 [23].

A recent intervention to increase the yield of tree species is applying a sustainable fertilizer called Argrow based on a nitrogen-rich amino acid arginine, which is rapidly absorbed by plants [24]. The same newsletter mentions the use of 'seedpads' to improve the germination of pine (*Pinus sp.*) and spruce (*Picea sp.*) seeds as well as an award given to Dr. Chris Harwood for his work advancing the understanding of breeding *Eucalyptus sp., Acacia sp.* and *Grevillea robusta.* – southern oak [24].

Protecting Water Resources

Many watersheds are being converted to agricultural areas or trees are being over-cut. This is subjecting such areas to flash floods, causing mud slides and the destruction of property and agricultural land. It also diminishes the flow of water, thus affecting the livelihoods of the surrounding population. The REDD+ programme (Reducing Emissions from Deforestation and Forest Degradation) could and should be used to save such areas: they should be given priority.

In India and Pakistan, groundwater from aquifers is being overused for agricultural production. This cannot continue and improved irrigation methods have to be used if the groundwater is to last. Otherwise food production may have to rely on rainfall, with a fall in yields, and some agricultural land will be abandoned!

Forest Ownership

Most forest areas in the tropics are owned by governments or local authorities, yet they are used or misused by the local people. It is the general consensus that if these areas are vested in the local people, management and sustainability will increase. It often leads to an increase in income for the people and the government. Thus, vesting forest resources in people at the local level should be given priority. If an area has to be protected for whatever reason, especially environmental protection of plants and animals, then the local population should be paid to protect it and be allowed to sustainably collect non-timber forest products (NTFP) and fallen wood for fuel etc. Deforestation has a very negative effect on animal species, reducing their habitat, and many more of them are likely to be endangered! Many forest areas, for example in the tropical forests of Brazil, are finely balanced ecosystems, if the trees are removed then the whole ecosystem may collapse and the soil becomes parched and un-useable. Similarly, if mangroves are cleared for shrimp farming or tourism, its rich habitat is destroyed and generally shrimp farming has to be abandoned in less than a decade because of disease to the shrimps. While mangroves mitigated the effects of recent tsunamis, other areas were devastated with great social and economic costs.

[2]This article was published in the African Journal of Food Science and Technology in September 2015. However, I the author made a calculation error and I overestimated the capture of carbon by a factor of 10. The CCS should have been 42 GtC not 420 GtC. I have adjusted the figures to account for this. Even so, CCS with wood is far cheaper than CCS from power plants.

Increasing Intermediate and End Use Efficiency

Fuel wood and charcoal are used by about half the world's population, principally for cooking and heating, but also by industrial and the service sectors: the latter two account for about 10% of annual consumption. At all levels there can be efficiency improvements. Much charcoal is produced inefficiently, mainly because in several countries production is illegal, (though not the sale or use). Charcoal producers are considered as the 'destroyers of the forest' whereas they are supplying a cheap and available fuel to many (poor) consumers. Generally, there is a sustainable supply of wood for charcoal production if managed properly. Rather than hindering the producers, they should be helped to improve the management of the resource, the use of the proper tools and equipment to improve charcoal kiln efficiency and be provided with market intelligence and training. In return the producers should be charged a fee for the wood raw material, which may be less that the bribes they pay to avoid charcoal confiscation! There are initiatives to increase the efficiencies of wood and charcoal stoves. These should be encouraged, especially by local producers. There are many publications on improved stoves, one of which is *Cleaner Hearths, Better Homes* by Barnes, Kumar and Openshaw [25].

Food Production, Storage and Consumption

Ways to improve food production have been mentioned above, but food storage may be a problem through poor storage facilities, rodents and other pests and lack of transport to market etc. Such problems should not be difficult to solve. However, one major challenge is changing eating habits. As people become richer, their diets change and the consumption of animal proteins increases. In many countries, especially in Latin America, forests and woodlands are being cleared for commercial crops and pasture to meet the need to increase animal proteins. Plant proteins require about 20% of the land to supply the equivalent amount of protein from animals. Changing eating habits is a large challenge, but it has to come sooner rather than later if global warming is to be brought under control.

Improved Infrastructure and Education

One of the drawbacks in many tropical countries is poor infrastructure. Lack of good communications curtails many rural people from marketing their products and receiving necessary services and appropriate training in crop production etc. Education is generally poor, especially for girls. There has to be increased emphasis on improved infrastructure and education if the rate of forest clearing is to be curtailed and population increase is to be tempered.

Tempering Population Increase

The tempering of population increase seems to be a taboo subject when discussing global warming and climate change. Population increase is one of the principal causes of deforestation, yet many governments and international bodies are reluctant to promote family planning etc. China is one exception and the imposition of the 'one child' policy on most of the population has tempered population increase, although this policy has now been relaxed somewhat. It may be coincidental, but China is increasing its forest area and the latest FAO figures give an annual increase of 308,000 ha over the period 2010-2015 [6].

When I was born, the World population was an estimated 2.3 billion, now 82 years later, the present-day population is over 7.6 billion: during that time over 1 billion ha of forests have been lost (88% tropical) [6,7,26]. By 2050 it is forecast that population will grow to over 9.7 billion if nothing is done to temper population increase. Most of the increase will be in LDCs, which by then may house 78% of the population on 55% of the land area. By 2100, the world's population could reach 11.2 billion. Sub-Saharan Africa's population is estimated to more than double by 2050 to over 2 billion and may reach 3.9 billion by 2100 [9]. Therefore, for the sake of the planet and *Homo sapiens* in particular, a concerted effort should be made to temper population increase.

It is instructive to compare the demographic trends of two countries – Tanzania and Thailand - that in 1970 were at a comparable level of economic development. From that time, Thailand pursued a vigorous family planning policy, whereas in Tanzania, little effort was made in the field of family planning. Table 2 examines population growth and increase in gross domestic production from 1970 to 2018 in both countries and illustrates the contrast.

Year	TZ	TH	TZ	TH	TZ	TH	TZ	TH
	Population growth rate		Population		GDP		GDP per capita	
	% per year		million		US$x10^9		US$	
1970	3.1	2.9	13.6	36.9	1.90	7.09	140	192
2018	3.0	0.3	58.6	68.4	55.65	490.12	949	7,163

Table 2: Population and GDP growth from 1970 to 2018 in Tanzania and Thailand.
Note. TZ = United Republic of Tanzania. TH = Thailand. Land area: TZ 94.5 million ha, TH 51.3 million ha. Purchasing Power Parity (PPP) in 2018: TZ. $2,789. TH, $18,032. GDP = Gross Domestic Production.

In 1970, Tanzania had only 36% of Thailand's population, but by 2018, the Tanzanian population was 86% that of Thailand and by 2024, the populations may be on par at about 69 million. By 2100, the population of Tanzania could be over 299 million, whereas that of Thailand is forecast to shrink to about 42 million [9]. Per capita GDP is 7.5 higher in Thailand compared to Tanzania (6.5 times higher in Purchasing Power Parity terms). Between 1970 and 1990 Tanzania lost an estimated 600,000 ha of forests per year and from 1990 to 2015 the loss was 400,000 ha/yr. for a total loss of 22 million ha over the 45-year period. FAO [8], whereas in the same period Thailand had a net loss of 10.6 million ha. However, from 1970 to 1990 the loss was 13 million ha or 650,000 ha per year, but from 1990 to 2015 the forest area *increased* by 2.4 million ha to 16.4 million ha or 96,000 ha/yr. [8]. What is more, its forest policy aims to increase the forest area to 20.5 million ha [28] (Figure 1).

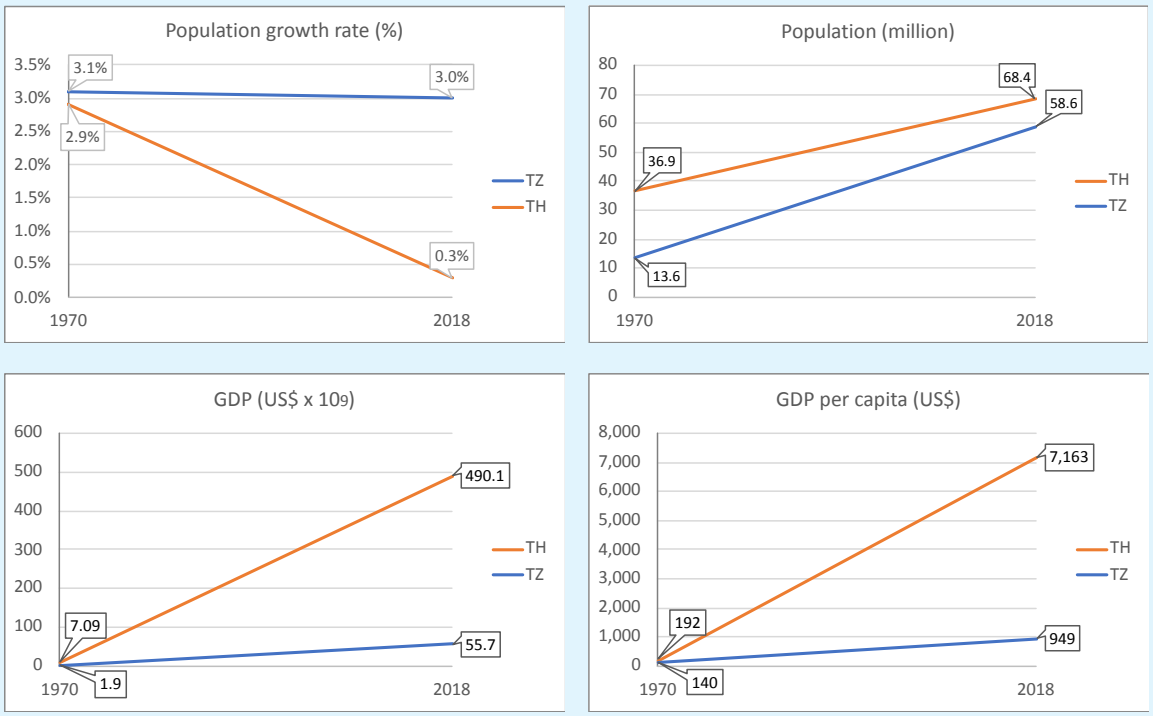

Figure 1: World Economic Outlook: International Monetary Fund [27], Population Pyramid 2018. Other factors that may influence population growth rates are education and existing infrastructure etc.

Because of the slower increase in population in Thailand, more money was put into productive activities and expanding infrastructure such as (rural) electrification and road building: farmers were also given more subsidies. In contrast, Tanzania had to devote more resources to schools, hospitals and food imports etc. Over the period 1970 to 2018, Tanzania's per-capita GDP only increased 7 times, where as that of Thailand increase 37 times! Thailand has only 54% of the land area of Tanzania, (51.3 million ha compared to 94.5 million ha),

but most of the land is far more productive and its average annual rainfall is over 1,500 mm. In contrast the average annual rainfall in most parts of Tanzania is under 1,000 mm. In 2015 Thailand exported 9.8 million t of rice out of a production of 27 million t, [28] whereas, Tanzania had a net import of cereals valued at $20.5 million [30]. It is difficult to see how Tanzania can meet the future food and other natural resource requirements of its population without a vigorous family planning policy like that of Thailand.

In sub-Saharan Africa, Tanzania is not an exception when it comes to promoting family planning. This is why SSA's population is forecast to more than double by 2050. Botswana is an exception. Through a vigorous family planning initiative, over a 50-year period, the birth rate has fallen from 7 to 3 children per woman and infant mortality rate has declined. The programme is partly supported by the International Planned Parenthood Federation, but two of its family planning centres have been closed due to President Trump's reinstatement of the 'global gag rule', which prohibits US federal funds going to any group that performs or even provides information about abortion [31].

Outside SSA, there are many LDCs whose population is expanding rapidly such as those in the Indian sub-continent, Brazil, Indonesia and the Philippines. Education, especially for girls, is a key area to promote family planning. Family planning should be part of the school curriculum with easy access to free or cheap birth-control devices such as condoms. In some countries such as Pakistan, the World Food Programme (WFP) provides tins of cooking oil to the family if parents send their daughters to school (personal observation). Such an initiative should be expanded. Health workers (bare-foot doctors) should pay many visits to rural areas to promote family planning. Local women of stature should be trained, equipped and paid to encourage youths and adults of child-bearing age to practice birth control.

Job opportunities

In future, robots and artificial intelligence may deny many people job opportunities, especially in urban areas. Thus, people may be forced back to the land. But in rural areas, job opportunities, especially for women could be expanded. The above carbon, capture and sequestration (CCS) proposal is an excellent way to expand employment opportunities. Rural people, especially women could start tree nurseries, plant and manage trees, protect forests, have stove-building enterprises, and expand the collection, manufacture and sale of wood and non-timber forest products. Plots should be established to demonstrate agro-forestry methods and free seeds, especially of appropriate nitrogen-fixing species, should be made available. All rural schools should have tree nurseries and children should be taught environmental awareness etc. Again, much more effort and money must be provided to promote family planning as in Botswana, China and Thailand. Such 'population' and 'agricultural' initiatives may require an amount of money equal to or more than the above proposed budget for CCS, but without these programmes, the slowing down of deforestation, even with such programmes as REDD+, may be fighting a losing battle. Those in authority should trust the (rural) people and take them into their confidence. Bureaucracy must be reduced to a minimum. Plantation areas can be checked by satellite, with some ground truthing. It is proposed that rural people willing to plant and manage trees, especially in the tropics, should be paid an appropriate amount of money on a per-ha basis and once the carbon is (fully) captured in the wood and forest soils additional amounts of money could be paid from say the 'green carbon fund'. Money for planting and management should be handed directly to the people or through trusted chiefs and NGOs etc. This should assist many people, especially the rural poor in developing nations, and be an essential part in the quest for reversing forest loss, GHG mitigation, environmental protection and increased forest and agro-forest areas: this should and could lead to truly sustainable development.

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