Evaluation of Wood Fuel Exploitation and its Relative Consumption Pattern in Kaduna Metropolis

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Abstract

It was discovered through an on-count method that a total of 1908 vehicles transport fuelwood where 964 were Lorries, 636 Trucks and 308 cars were recorded for 3hrs per day and in 12 weeks. Also, 100 respondents each agreed that a lorry or truck is utilized per week and 40 respondents, cars. Therefore, a linear correlation using Pearson's product-moment correlation coefficient analysis shows there is no significant relationship between fuelwood exploitation and its relative consumption in Kaduna metropolis (Ho: $P_1 = P_2$ (or $P_1 - P_2 = 0$). Where the t value showed 6.314 at df = 1 and $\alpha = 0.05$ and the calculated value shows 1.136 has no correlation between exploitation and consumption pattern of the sample data. Therefore, from this study it was found that fuelwood exploitation has a technique that is basic for sustainable utilization and it ensures a safe environmental standard unlike fossil fuel components in the environment.

Keywords: *Fuelwood, transportation, Utilization, Consumption, Environment and Safe.*

Introduction

The burning of wood is currently the largest use of energy derived from a solid fuel biomass. Fuelwood can be used for cooking and heating, and occasionally for fueling steam engines and steam turbines that generate electricity. Fuelwood may be available as firewood, charcoal, chips, sheets, pellets, and sawdust. The most important sources of fuel, which are the necessities for man kind, are fuel wood (charcoal and firewood), petroleum and peat. Of these, wood makes an outstanding fuel as it is 99% flammable if completely dry (Hill, 1952; Kochhar, 1998). The particular form used depends upon factors such as source, quantity, quality and application. Sawmill waste and construction industry by-products also include various forms of lumber tailings. Some consider fuelwood bad for the environment; however this is not the case if proper techniques are used. One might increase carbon emissions using gas powered saws and splitters in the production of firewood, but when wood heat replaces carbon-producing fuels such as propane, heating oil or electricity from a coal-burning plant, then wood burning has a positive impact on the carbon footprint.

One of the major and most renewable natural resources available to the earth and man at large is forest and its products. It was the earliest utilizable natural resources until now that other resources have sufficed human needs. There is more to wood consumption than just its local utilization and it initiated the basis of industrialization. Demand for firewood, including from

woodland species, can be reduced by increasing the efficiency of firewood use, as well as by increasing the use of alternative fuel sources, such as plantation timbers and manufactured fuels.
In Kaduna metropolis, there are a number of Bakeries and large canteens, which are the major target as far as fuelwood is concerned. Many consumers depend on locally baked bread which is cheaper and affordable to the common masses. Also, fast local food restaurants meet the instant need for food available in areas of the metropolis. The aforementioned depend mainly on fuelwood consumption on daily and large basis.

Increase in the efficiency of firewood use is likely to reduce the emission of greenhouse gasses. While there are significant uncertainties about greenhouse gas emissions from fossil burning. In our various homes under various operating conditions, in general the more efficient use of firewood will have greenhouse benefits. Overtime, there is evidence to prove that there will be change in climate, the distribution of climax plants formation than occurred in historic period, and still continues. It was also discovered that there had been such changes in recent theological period. It was shown that there might have been climatic fluctuations in West Africa, but believed that there is no circular climatic trend and the evidence came from historical files. He pointed out that the distribution of Northern Nigeria vegetation in 1822 – 1824 by Denham and Clapaton indicated conditions like those of today. From this one will attribute any shift southwest from human activities.

The geological data that is, the fact remains; fossil, soil, geomorphologic development point to the existence in tropical Africa of web period when the evergreen forest extended from beyond its present limit.

Natural Phenomenon

The geo-distribution of national resources can be argued giving the indices of more fossils to the Southern regions because of the cloud formation. The dense nature of the atmosphere can curtail the emissions unlike the Northern region aridity would result to a faster deterioration of the climate. Therefore, wood burning can be adopted as soon as alternative firewood is promoted as one of several commercial products from landscape regeneration programs.

Climate change, attributed to human-induced emission of greenhouse gases into the atmosphere, is widely recognized as having potentially serious impacts on the global environment. Since the industrial revolution, atmospheric CO2 concentrations have increased from approximately 280 mmol mol_1 in 1750 to 365 mmol mol_1 at present, and will exceed 700 mmol mol_1 by the end of the present century if emissions continue to rise as predicted (IPCC 2001). In Europe, warming has been detected in the form of an increased mean annual air temperature of between 0.38C and 0.68C since 1900. Further increases of as much as 28C above the 1990 levels have been redirected by 2100 using climate models (EEA 1998). There is now little doubt that climate is warming on a global scale, but change at a local level may be more variable and subtle and therefore more difficult to detect (IPCC 2001). One approach to assessing effects of climate change at a local level is through establishing the relationships between developmental processes in living organisms (phenology) and seasonal climatic conditions and using these relationships as indicators of ambient climate. Phenology is the study of the timing of periodic biological events in the animal and plant world as influenced by the environment (Schwartz 2003). Records of long-term phonological observations on trees, such as the dates of leaf unfolding, flowering, leaf discoloration and leaf fall, provide historical information to indicate how plants have responded to variations in climatic conditions. There has been interest for many years among natural historians in the recording of phenological events, particularly across Europe.

For example, the Royal Meteorological Society established a phenology network in 1875 (Sparks et al. 2000a) and Finnish phenological records go as far back as 1748 (van Vliet and de Groot 2001). Despite changes in recording methods since the initiation of these programmes, the importance of these historic records as indicators of environmental and climate change is now well established (Sparks et al. 2000a) and examination of long-term phenological data sets has provided measures of biological responses to climatic variation (Sparks and Carey 1995). However, interpretation of these data records, in terms of identifying the exact causal relationship between climate and development, and extrapolation to larger geographic regions presents a challenging problem for environmental modelers (Schwartz 1999).

The standard of living of man has been a major concern since forest became restricted to its optimum utilization and the exploration of fossil products. This has shown that a great repulse to the relationship between man and the forest that is, man is gradually loosing understanding with the forest and his environment. Also, there are only few benefits from the national treasure as it takes superiority over other resources and sources of income, giving the need to revitalize the fuelwood systematics and the world from preventable disaster.

Wood Energy

Energy is a limiting commodity for many communities in the developing world, and the rural communities in Africa are highly dependent upon wood as their primary energy source (Arnold & Jongma, 1978). For example, in South Africa 12% of the total energy consumption of the country (i.e domestic and industrial) is extracted from wood source, while in countries such as Burkina-Faso, Ethiopia, Mali, Tanzania and Zambia, this figure is in excess of 90% (Basson, 1987; Osei, 1993). The few states that have been done on that wood utilization have achieved issues concerning sustainable utilization (Liegme, 1983; Shackleton, 1993; Osei, 1993), history of legalized protection of wood resources (Cooper & Swart, 1992), economics of fuelwood usage, and future energy demand (Basson, 1987; Osei, 1993). No study in Africa has examined the impact of fuelwood removal on components of biodiversity other than the wood resources itself, even though it has been recgnised that this practice may have consequences for conservation (Cooper & Swart, 1992; Joshua & Jonsingh, 1994).

Effective conservation practice demands the maintenance of biological diversity and ecological processes within the constraints of sustained resources utilization. Few areas in indigenous forest in Southern Africa are free from exploitation, both commercial and subsistence, and extensive fragment of natural forests has occurred.

Roundwood used in energy production is comparable in quantity with industrial roundwood. Energy production using wood includes traditional heating and cooking with fuelwood and charcoal, heat and power production in the forest industry (usually using processing wastes such as black liquor from pulp production) for own use or sale to others, and heat and power generation in specifically designed power facilities. Statistics on energy production from wood are difficult to obtain because of this diversity of uses and the high share of informal production. Furthermore, the two main agencies that collect these statistics – FAO and the International Energy Agency (IEA) – present different figures because of different definitions and primary data sources. IEA presents biomass energy production figures that include other types of biomass besides wood (i.e. agricultural residues and dung). Its statistics also include heat and power generation in the forest industry and by commercial energy producers, which are not fully captured in FAO statistics. Trends and projections for biomass energy production estimated from a combination of these two data sources reveal an increase in global production from about 530 million tonnes oil equivalent

(MTOE) in 1970 to about 720 MTOE in 2005, projected to reach 1 075 MTOE in 2030. Interpolation suggests that wood used for bioenergy production increased from about 2 billion cubic metres in 1970 to 2.6 billion cubic metres in 2005. This suggests that up to 3.8 billion cubic metres of wood could be required by 2030. However, some of the future demand may be satisfied by biomass produced from agricultural residues and energy crops (including short-rotation coppice and grasses). Until 2005, global biomass energy production increased relatively slowly, at less than 1 percent per year. Most of the increase in production occurred in developing countries, where wood continues to be a major source of energy. The exception is Asia and the Pacific, where growth has declined considerably because of switching to other preferred types of energy as a result of increasing income. The projections reflect a future marked increase in the use of biomass for energy production in Europe and, to a lesser extent, North America as renewable energy policies and targets take effect. Europe's per capita biomass energy use is projected to triple by 2020 in response to renewable energy targets, although some production will also come from energy crops and agricultural residues. Most developed countries have set renewable energy targets for 2020; hence, rapid growth in production is expected until that time, followed by a slower rate of growth. Furthermore, future large-scale commercial production of cellulosic biofuel could increase the demand for wood drastically, beyond that shown in the projections. The projections for biomass energy production in developing countries also have interesting features. As a consequence, in the Guinea Savannah zone, the gap between demand and fuel wood supply is widening. In 2005, only about 23 % of the fuel wood consumed in this zone originated from the area. This means that 77 % of wood consumption in the area is unsustainable, i.e. is Non-Renewable Biomass. Kaduna State is situated in this zone. Therefore, Kaduna State, like other States in Northern Nigeria, is not self sufficient in terms of fuel wood supply. In the Sudan Savannah zone, the situation is even worse. In 2005, only 13.7 % of the demand was covered by production in the area, according to the FAO.

Consumption of Fuelwood in Nigeria

"The consumption of fuel wood and charcoal remains based on the early data by FAO as reported by EMRD (1991). This is based on a per capita fuel wood and charcoal consumption of 0.5 t/cap/year and 0.2 t-charcoal/cap./year and projected for the national population as available from the 1991 population census at projected at 2.8% growth rate per year". However, due to rising prices for fossils fuels, a massive shift from "modern" fuels like Kerosene and LPG back to fuel wood and charcoal has been taking place.

To calculate the consumption of wood fuel, the amounts of wood used for charcoal making and fuel wood have to be summed up. If we apply a weight-related conversion factor of 4.5 for charcoal making (the volume-related FAO default value is 6:1), wood fuel consumption is about 1.4 kg/head/day; or the energy equivalent thereof in fossil fuels.

R.A. Cline-Cole & et. Al., (1987) reported a fuel wood consumption of 360 kg/person/year (excluding wood used for making charcoal) in neighbouring Kano State. There is an obvious competition between surface needs for agriculture and wood production. "Crop production in Nigeria is currently dominated by resource-poor farmers with little or no access to productive resources. More than 90 % of these are small holder farmers cultivating less than 2 ha farm holdings and because of this, they cultivate marginal and environmentally fragile land areas. This practice has led to land degradation and deforestation, erosion and lowland flooding, degradation of watershed protection and declining resilience in ecosystems.

The rate of deforestation of the woodlands average 3.5% in 1980-90. It has been projected that Nigeria's remaining forest may likely disappear in 2020". The effects on CO2-emissions are categorized under "emissions from land use change and forestry".

Emissions from Land Use Change and Forestry

Additional information on the non-sustainability of wood fuel demand and production can be obtained from the comparison of carbon uptake and release in relation to land use changes. In some cases, these changes provide some uptake of CO2, mainly following re-growth of vegetation on abandoned land, but this effect is small compared to the conversion of forests for other uses.
"Results indicate that energy and land use change sectors contribute highest to CO2 emissions, while CO2 contributes more than 70 % to gross equivalent emissions. Thus, the energy and land use change sector, and the reduction in national emissions for CO2 should be the first step towards sustainable management of future GHG emissions in Nigeria". In the years 1988-2000 the percentage contribution of "Land Use Change and Forestry" to total emissions oscillated between 38.5 % and 47.8 %.

The shift from fossil "modern" forms of energy like kerosene or LPG back to fuel wood

"The unsustainable level of production of fuel wood in Nigeria is likely to continue for some time as long as the energy crisis facing the country remains unresolved. The country still witnesses erratic supply of petroleum products (Kerosene and Gas), and when available the prices are beyond the reach of ordinary people. The implication is not far-fetched, as more people will resort to fuel wood, which is already in short supply" (FAO 2003, Experience of National Forestry Programmes in Nigeria). The situation in 2007 is still the same, if not worse. This means that people are reverting from modern to traditional forms of energy ("reverse substitution with wood fuel", according to the FAO).

Need for Firewood Utilization

In an area of cleared vegetation, regeneration enhances essential control of dry land salinity and restores landscape biodiversity. Regeneration could provide a useful carbon sink and the basis for sustainable regional firewood industries. Some time, old and dead trees often with hollows and fallen timber are preferred sources of firewood, as they tend to burn well and produce less smoke. However, these same trees also provide crucial habitat and food, nesting hollows, perching places and forage substrate for birds and arboreal mammals, including Nigeria's most threatened ecological communities and wildlife. In Uganda, over nine-tenth of energy requirements is based on wood obtained from the forest (Anon, 1994)

Over nine-tenths of Uganda's energy requirements is based on wood obtained from the forests (Anon., 1994). Fuelwood is a major source of domestic and industrial energy. It is used in the processing of agricultural products such as tea, tobacco and sugar; in the construction industry for baking bricks, tiles and lime; and in fish processing. However, the country's dependence on biomass energy resources is a source of great concern because gazette and non-gazette forest resources from which most of the firewood is harvested are depleting rapidly due to population increase. It is estimated that deforestation in Uganda is occurring at the rate of 650 km2 annually (FAO, 1993). Lack of a mechanism to control harvesting of fuelwood in non-gazette forests encourages excessive depletion. There is a need for an organized management institution to oversee the utilization of

non-gazette forest resources to avoid a situation that Hardin (1968) described as "the tragedy of the commons." A significant question to ask at this stage is: How can common pool natural resources be managed and exploited in a way that avoids both excessive consumption and high administrative costs? It has become clear that neither state control, nor privatization of institutions has been uniformly successful in empowering individuals and communities to manage natural resources sustainably (McKean, 1998).

The increase in the bioenergy use is expected to come mainly from forest resources, and the remainder from agricultural and biological waste residues. The volume of standing forest in Slovenia has been steadily increasing for many years. The utilization of bio-energy for heating purposes depends on costs, both the cost of the bio-energy itself and the cost of alternative energy sources and fuel oil being the most common one. A significant increase of the actual energy produced from firewood in Slovenia could be achieved by promoting better fuel quality management, improving firewood production and supply chains and promoting the use of more efficient combustion appliances with less environmental impacts. This will in addition to increasing the quality of the use of firewood contribute to achieving Slovenia's national bio-energy goals and our Kyoto Protocol obligations.

Materials and Methods

In Kaduna metropolis there are three major Local Government Areas which are North, South and Kaduna Central respectively. The study area is Located at 10^0 35′ 0″ N, 7^0 29′ 54″ E axis of the globe. It comprises of various tribes and cultures from all walks of life. Business activities cannot be overemphasized as the populace engage themselves in various trades including firewood business on a large scale.

Sampling Procedure

This work is targeted to provide information on the rate of firewood consumption. Well structured questionnaires were administered to major bakeries, canteens and retail consumers of notable usage of firewood. Also, "on count" method was adopted to obtain the number of truck or lorry load for 3 hours per day, three times a week and 12 weeks. Likewise, exploitation field of firewood production was visited for further information on suitable species of trees exploited solely for the purpose of firewood.

Sampling Technique

Five major bakeries, canteens and retailers were randomly selected respectively. Fifty well structured questionnaires were administered to each selected area in ratio 2:1:2 that is, 100 for the bakeries, 100 for the retailers and 50 for the canteens respectively, making a total of Two Hundred and Fifty Questionnaire. Also, every loaded truck, lorry or car was counted for at least three hours per day for 12 weeks. Likewise, pictures or images of a current status of the firewood production area will be provided.

Analytical Tool

From the results derived in the course of this research, data collected was subjected to Pearson's product-moment correlation coefficient to measure the linear relationship between sampled data.

Test of Hypothesis

Ho: $P_1 = P_2$ (or $P_1 - P_2 = 0$)
H_A: $P_1 \neq P_2$ (or $P_1 > P_2$ or $P_1 < P_2$)

In the hypothesis testing, shows there is no significant relationship between fuelwood exploitation and its relative consumption.

Results

The study was dependent on so many variables needed to obviously reveal the most consumed quantity of firewood and the rate pattern at which this is done. In this chapter, tables, charts and pictures are used to express data. Also, inference will be drawn to interpret the hypothesis.

Socio-economic Characteristics of the Respondents

Table 1: *Showing Gender Distribution of the Respondents*

Gender	Frequency	Relative frequency
Male	125	52.08
Female	115	49.92
Total	240	100

Source: Field work, 2012

The table above shows the gender distribution of the respondents as a vital factor to be considered in the socio-economic characteristics of the respondents. From the result, 52.08% of the respondents are male while 49.92 0f them are female. This shows that there is a sort of gender equality in the distribution of the respondents though more men are involved in the firewood utilization than women.

It was also noticed that men are more in both the major bakeries and canteens as the respondents declared men are more versatile than women and more work is covered per unit time and area with men at work.

Table 2: *Showing Age Range of Respondents*

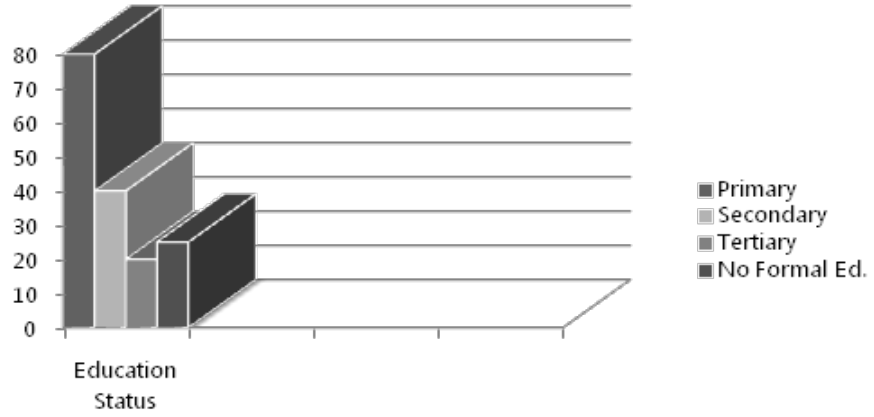
Age Range	Frequency	Relative Frequency (%)
20-30	95	39.60
31-40	48	20.0
41-50	59	24.60
51-60	38	15.80
Total	240	100

Source: Field work, 2012

In the table above, it is shown that the percentage relative frequency of the ages of the respondents cannot be under-estimated as the youth (20-30years) shows their involvement in firewood utilization by taking the lead with a value of 39.60% while the rest of the age classes are 24.60%, 20.0% and 15.18% respectively. This is relatively true about the age class distribution because the youth are the more vulnerable in terms of lack of employment and would take up any in the absence of none. The respondents in the age class of 51-60 are some worth owners of the bakeries and canteens.

Besides the age differences, the hauling of materials and even the fuelwood require the hands of able workers are still relatively young and agile and the more reason for the employment of the youth to manage and fulfill the set goal and objective. Also, another reason is the management of risk that is most works are now exposing workers to risk especially in the aspect of time beating.

Figure 1: *Showing the Education Status of Respondents*



Source: field work, 2012

From the chart above, it was realized that respondents with primary education earned a minimum of primary education and are found to be more among the casual with 80 respondents, followed by it is the bar with secondary education with a value of 40, tertiary education has the lowest with 20 points and respondents with no formal education has 25. This shows that the level of education has been quite a major factor especially in an economic unit where human hygiene matters. Education is the key to a healthy environment and a healthy living.

Figure 1: *Showing a row view of the fuelwood hips*

Source: Field work, 2012

This shows that between the volumes of 108m^3 and 673.2m^3 are hipped on the site. It was known further that there are 22 numbers of hips in the area. So, the total volume ranges between 2376m^3 and 14810.4m^3 on a hip site.

Conclusion

The exploitation of fuelwood has been known to be an inexhaustible source of energy for man from time immemorial and this is a fact that will never change. This research proved that forest trees especially those used for fuelwood exploitation are only depleted with use of sophisticated machine like the chainsaw or power saw machine that tend to disrupt the active cell for re-growth or coppice. It also reveals that this is an uncommon type of regeneration system which is practiced to ensure sustainability. In the results, more men are more involved in firewood utilization than women, showing that more of them are youth with a relatively low education status (primary education). This utilization was also shown from the result to have no correlation or relationship with exploitation that is, they both independent activities executed with time. Pictures also show the extent and species type of the exploited trees which related the volume of the entire fuelwood hipped for transportation.

Therefore, in Kaduna metropolis, fuelwood utilization is prospective for sustained yield management and industrial fuelwood practice. This will enhance improved technology of green fuel or wood burning using improved devices and increase the rate and support for fuelwood plantation having known the tree species most suitable and common in the fuelwood trade. It will also improve the climatic condition of the world at large if it is realized the great benefits fuelwood burning has over fossil fuel.

References

Abbiw DK (1990). Useful plants of Ghana: West African uses of wild and cultivated plants. Intermediate technology publications, London and the Royal Botanic Gardens, UK, p. 337.

Arnold, J.E. & Jongma, J. (1978). Fuelwood and charcoal in developing countries. Unasylva, 29, 2-9.

Banks, P.E & Meterlerkamp, H.R.R., (1979). A comparison between the cost of growing Eucalyptus grandis for fuelwood and the cost of coal in Zimbabwe Rhodesia. S. Afri. For, 117, 16-18.

Basson, J.A. (1987). Energy implication of accelerated urbanization. S. Afri.J.Sci, 83, 294-8.

Cooper, K.H., & Swart, W. (1992). Transkei from survey Wildlife Society of South Africa, Durban.

Joshua, J & Johnsingh, A.J.T. (1994). Impact of biotic disturbance on the habitat and population of the endangered grizzled giant squirrel, Ratufa maraura in South India. Bio. Conser, 68; 29-34.

Cline-Cole R.A. et al., (1987). "Wood Fuel in Kano, Final report of the Rural Energy Research Project", Bayero University, Kano, Department of Geography, http://www.odi.org.uk/fpeg/publications/greyliterarture/fuelwood/Clinecole/index.html

Cotton CM (1996). Ethnobotany: Principles and Applications. John Willey and Sons Ltd. Chichester, p. 424.

EEA 1998 Europes environment: the second assessment: Office for the official publications of the European Communities. Oxford, UK. Elsevier Science Ltd.

FAO: "Experience of Implementing National Forestry Programmes in Nigeria", http://www.fao.org/DOCREP/005/AC918E/AC918E04.htm

Hill AF (1952). Economic Botany: A Textbook of Useful Plants and Plant Products. 2nd ed. McGraw-Hill Book Company, Inc., New York, p. 560.

IPCC 2001 Climate Change 2001: The Scientific Basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change. T.J. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson (eds). Cambridge. Cambridge University Press.

Kochhar SL (1998). Economic Botany in the Tropics. 2nd ed. Macmillan India Limited, New Delhi, p. 604. Osei, W.Y. (1993). Woodfuel and deforestation answers for a sustainable environment, J. Environ. Manage, 37, 51-62.

Ray, James, "Wood Usage in Rural Tanzania: An Investigation into the Sources and Accessibility of Fuelwood and Polewood for the Residents of Kizanda Village, West Usambara

Mckean M.A. 1998. Common Property: What is it, what is it good for and what makes it work? In: Gibson, c., Mackean, M. and Ostrom, E. (Eds.), Forest Resources and Institutions. Rome: FAO (Forests, Trees and People programme, Phase II, Working paper No.3). pp 23-47

Mountains" (2011). ISP Collection. Paper 984. http://www.digitalcollections.sit.edu/isp_collection/984 "Wood-Burning Power Plants--Carbon-Neutral or High Carbon Emitters?: Scientific American". http://www.scientificamerican.com/article.cfm?id=wood-burning-power-plants-carbon-neutral-high-emitter.

Schwartz, M.D. 2003 Phenology: an integrative environmental science. The Netherlands. Klewer Academic Publishers.

Shackleton, C.M. (1993). Fuelwood harvesting and sustainable utilization in a communal grazing land and protected area of the eastern Transvaal lowveld. Boil. Consv.63, 247-54. Slovenian Forestry Institute URL http://petelin.gozdis.si/splet/index.php.

Sparks, T.H., Jeffree, E.P. and Jeffree, C.E. 2000a An examination of the relationship between flowering times and temperature at the national scale using long-term phenological records from the UK. International Journal of Biometeorology 44, 82_ 7.

Sparks, T.H. and Carey, P.D. 1995 The response of species to climate over two centuries: an analysis of the Marsham phenological records, 1736_ 1947. Journal of Ecology 83, 321_ 9.

Van Vliet, A. and de Groot, R. 2001 Phenology and climate: evidence of change. Change 56, 12_ 14.