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# Detection of Dust pollution using a Ka-Band Doppler Radar in a Tropical Location of West Africa

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## Abstract

Apart from posing as leading cause of respiratory ailment, dust pollution over West Africa is known to hamper flight operations by reducing visibility during the dry season. Inspection of visibility is usually made through visual observation by meteorological observer, it accurate estimation therefore depends on the visual judgment of the observer. Also profile observations of atmospheric dust are not included in visibility record of meteorological stations. Much of the dust load in the atmosphere is held up in a layer above the surface which could descend to ground level resulting into poor visibility or lifted leading to clearance. In this paper, a method of dust pollution detection using radar reflectivity has been developed. Through this method, atmospheric dust load could be estimated and converted to visibility. Results of comparison between radar-derived visibility and observation show a good agreement with correlation coefficient of 0.81. Consequently, dust load beyond the reach of visual observation could be made enhancing atmospheric dust load prediction for aviation and health purpose among others.

**Keywords:** Radar reflectivity; Aerosol dust; Pollution; Visibility; Particulate matters

## Introduction

Radiative properties of atmospheric dust aerosol significantly affect surface radiation balance when greater percentage of the incoming solar radiations is reflected back to the atmosphere due to presence of dust particles. The radiation effect may as well have direct relationship with crops performance when radiation budgets are alter dramatically. Apart from general radiative balance, the impact of dust presence in the atmosphere over West Africa appears to be diverse. Dust emanating from the Saharan and Sahel part of West Africa has been analyzed and found to contain lot of minerals and chemical compounds that alter the biogeochemical cycle over both land and ocean. Part of dry Sahel support Agriculture where inorganic fertilizer containing chemical compounds are used to boost agricultural production. These chemicals compounds are carried along with loose dust particle during the period of dust mobilization to distant locations where it will deposit as a form of nutrient to enrich the soil [1] and perhaps inhaled by human. Dust inhalation poses a threat to human health and has been reported to be a leading cause of epidemic such as meningitis [2]. Similarly, the presence of dust greatly reduces air quality and horizontal visibility. Poor air quality as a result of dust is often led to hospitalization for various respiratory diseases such as cough, allergic reactions, asthma and sore throat.

Good horizontal visibility is one of the essential conditions for effective and smooth aviation operations. Impaired visibility could lead to accident, flight cancellation and delays. Early dust outbreak detection could ameliorate most of the problems related to dust pollution and hospitalization. Various methods of dust detection have been employed over years which include satellite measurements. As early as 1972, estimation of dust concentration in the atmosphere has been carried out when Prospero and Carlson [3] used satellite images (AVHRR) to derive dust emission estimates emanating from over West Africa to Florida and the Caribbean. Measurements from AVHRR were verified to be inadequate in monitoring dust pollution because it failed to distinguish between smoke, stratospheric aerosol, sea salt and dust pollution. Total Ozone Mapping Spectrometer (TOMS) uses spectral difference between two contrasting wavelength to estimate and distinguish between absorbing and non – absorbing aerosols [4]. TOMS measurements have long records of aerosol dataset spanning between November 1979 to December 2006 from where Ozone Monitoring Instruments (OMI) took over. TOMS data are sensitive to aerosol heights and can be misleading while interpreting dust pollution trapped within the Planetary Boundary Layer (PBL). Another satellite-based dataset is Moderate Resolution Imaging Spectroradiometer (MODIS) which started in 1999 onboard of sun synchronous polar orbiting Terra (EOS AM) satellite and capture data in about 36 spectral bands. It provides accurate measurements of optical thickness. MODIS data can be used to estimate dust concentrations, flux and oceanic deposition [5]. Visual range observation is another method, but a ground-based approach, by which dust pollution can be measured. Generally this method is usually employed in determination of visibility for aeronautic operations at meteorological stations. Anuforom et al. [6] found good correlation (r= -0.92) between TOMS UV absorbing aerosol and horizontal visibility during the sub-Sharan Harmattan season over West Africa. Visibility data are not usually adequate in estimating large scale dust pollution because it is often recorded as point data which preclude spatial display of pollution over a large area. Since visibility depends on the visual capability of the observer, it suffers from observer's judgment and therefore unable to provide any information on the evolution of dust pollution. Ground instrumentations of various algorithms are available but Aerosol Robotic Network (AERONET) provides a global ground station aerosol dataset. AERONET (a ground –based observation) data had been used to test and improve dust emission and transport models [7], and analyze the characteristics of outbreak of dust episode. AERONET data is still very inadequate because of its spatial coverage, for example, only few stations cover the entire West Africa. Similarly, Chin et al. [1] used a ground based Thermo Scientific Tapered Element Oscillating Microbalance (TEOM) to sample PM10 over Cayenne and Guadeloupe. Like many ground based measurements, the campaign is limited to very limited coverage.

Radar system is also being used in dust pollution detection but much of works on this subject had been based on estimating the dust permittivity factors. The permittivity factor is necessary in designing higher frequency links for areas affected by dust storms. However, permittivity factor alone only provides vague information about dust pollution. Marzano [8] explored the potential of using weather radar to estimate volcanic ash and established the relationship between radar reflectivity factor, ash concentrations and ash fall rate. Islam et al. [9] explores the possibility of determining the visibility from radar attenuation and concludes that visibility varies between 10 m to 500 m for attenuation between 13 dbkm-1 and 0.2dBkm-1. Radar method of dust detection follows the principle of rainfall estimation where intense pulses of microwave are emitted and directed to hit object of interest. The reflected backscattered energy is transmitted to the receiver system of the radar. In rain-free atmosphere, attenuation of the emitted microwaves is usually due to atmospheric particulate matters. From this assumption, dust pollution detection at different layers in the atmosphere can be estimated. The focus of this research is on an attempt to detect dust pollution using the known characteristics of Sahara dust and Ka-band radar reflectivity factor. The specific objectives of this scheme are that (1) dust pollution at different atmospheric layers can be estimated by determining the atmospheric dust load using the radar attenuation characteristics. (2) Comparison between the radar estimated dust load and actual "visibility" will be explored to determine the radar "sensitivity" to dust pollution detection which is important to air quality management.

## Study Area and Method

Akure, (latitude 7.20o - 7.32o and longitude 5.13o - 5.26o) a city in Nigeria, shown in Figure 1, is tropical location with two distinct seasons namely; the dry season, which begins in November and lasts till March the following year and the wet season which starts with the pre-rainy period in March, spans through the peak of monsoon period in June/July and ends in October. Akure is typically a rainforest zone, which experiences a period of little dry season in August [10]. Average annual rainfall during the wet season is about 1500 mm while average temperature ranges between 21.4 oC and 31.3 oC per annum, annual average humidity also ranges between 45.4% and 100% [11]. The dry season is characterized by episode of severe pollution as a result of dust incursion into the area. The dust, which emanates from Sahara region of West Africa advects with the northeasterly winds blowing over the area, is a source of many pathogens causing acute respiratory problems in humans [12,13]. Air quality and flight operations are adversely affected as a result of dust circulation during this period.


Figure 1: Akure Google map showing the approximate location of (Lat 7.25°N, Long 5.20°E). Letter "F" is the location of Federal University of Technology, Akure where the MMR is sited.

## Radar specifics, measurement site and method of dust Estimation

Ka –band weather radar having technical characteristics shown in Table 1 was installed at the communication and research measurement site in the campus Federal University of Technology, Akure, Nigeria. There are some radar bands are actually not suitable for dust pollution detection. For example, Goldhrish [14] argued that attenuation of radar signal as at L -band may be considered negligible, meaning that such radar system may not detect dust accurately. Dust attenuation at Ka radar frequency is very high; dust detection using this band is also expected to increase in accuracy. The equipment at our site is 8 cm wavelength vertically pointing, MMR-2 radar, shown in Figure 2, which measures reflectivity at 64 spectral frequencies. The radar was configured to a vertical range resolution of 30 m and Pulse Repetition of 0.2 microseconds. The site is a tropical location that often experiences severe dust pollution during the boreal winter. During this period the Sahara dust migrates from the source regions of Faya Largeau, Bodele depression and parts of Western Sahara desert aided bydry but strong north easterly winds to the coast of Atlantic Ocean and beyond. In the process of dust migration, visibility downwind is always very poor with attendant hospitalization for respiratory related diseases. Goudie and Middleton [15] estimated that between 130 and 760 Tgyr-1 of dust are transported across West Africa. Weather over the site is also influenced by wet south westerly wind flow during the rainy season emanating from the Atlantic coast and extending to the fringe of Sahel savanna between March and September on annual cycle. Dust pollution during the rainy season is low and is mainly due to local sources.

## Expression for derivation of dust pollution

Dust particles are capable of reflecting electromagnetic wave sent out from radar back to the earth. This backscatter echo ( ) ( ) 0 Nr iii P ND PD = = ∑ is related to the diameter spectrum of dust particles ND NpD i N ( i oi ) = ( ) 0, = [ ] and can be expressed as in equation 1.

$$P_r = \sum_{i=0}^{N} N(D_i) P(D_i)$$

where P ND PD r ii ∑ ( ) ( ) is the probability that dust particle diameter lies within dust diameter spectrum per meter square otherwise known as particle probability. Zhang et al. [16] has shown that ( ) ( ) 0 Nr iii P ND PD = = ∑ , dust particle spectrum diameter ND NpD i N ( i oi ) = ( ) 0, = [ ] and total number of particles ND NpD i N ( i oi ) = ( ) 0, = [ ] are related by;

Table 1: Technical characteristics of the Ka-band radar compared to other radar bands.

| Radar system Characteristics | Radar Ka- band | Radar S- band | Radar C- band | Radar X- band |
|---|---|---|---|---|
| Band | K | S | C | X |
| Frequency | 24.23GHz | 2.70 – 2.90 GHz | 5.45 – 5.82 GHz | 9.375 GHz |
| Transmitter | Gunn-diode | Magnetron | Magnetron | Magnetron |
| Transmit Peak Power | 50 mW | 600 kW | 250 kW | 50 kW |
| RF Pulse Width | 0.2 μs | 0.8 -2 μs | 0.5 -2 μs | 0.5 -2 μs |
| PRF | 125,000 Hz | 250-5000 Hz | 250-2500 Hz | 250-2500 Hz |
| Antenna Type | Circ parabolic | Circ parabolic | Circ parabolic | Circ parabolic |
| Antenna Gain | 40.1 dB | 45 dB | 45 dB | 41.6 dB |
| Polarization | Linear H | Linear H | Linear H | H and V |
| Beam Width | 2.0° | 1.0° | 1.0° | 1.3° |
| Reflector diameter | 0.6 m | 8.5 m | 4.2 m | 2.1 m |
| Sensitivity (MDS) | -37 dBm | -113 dBm | -113 dBm | -112 dBm |
| Receiver Noise Figure | 2 dB | 2 dB | 2 dB | 2.3 dB |

Table is modified after Marzano, with inclusion of K-band radar characteristics.

, it is obvious this type of a degree is applicable to many employment fields. There are a variety of fields available for study, which would allow all potential students to choose a college with a specialty degree of their liking whether it is business or hands-on farm oriented. I have concluded from my study that a Master of Business degree with an agriculture specialty is a viable degree that is relevant to a divers employment field.

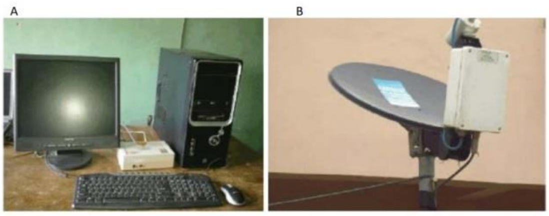


Figure 2: The MMR-2 unit (A) Indoor unit B) Outdoors unit.

ND NpD i N ( i oi ) = ( ) 0, = [ ] (2)

Combining equations (1) and (2) yields the relationship between echo power ( ) ( ) 0 Nr iii P ND PD = = ∑ , particle probability ( ) ( ) 0 Nr iii P ND PD == ∑ , total number of particle ND NpD i N ( i oi ) = () 0, = [ ] and the echo power per each particle ( ) ( ) 0 Nr iiiP ND PD = = ∑ is expressed in equation 3 according to Wang et al.[17];

$$P_r = \sum_{i=0}^{N} N_o P(D_i)\, p(D_i) \tag{3}$$

The density of dust particle is an important parameter, which indicates turbidity status of the atmosphere during a dust event and it is a measure of horizontal poor visibility. The relationship between density 7 3.79 10 w NT − = × and dust probability ( ) ( ) 0 N r iii P ND PD = = ∑ can be expressed as [14];

$$P_i = \frac{N(D_i)}{N_T} \tag{4}$$

Mass loading of dust is directly related to the dust density 7 3.79 10 w NT − = × and probability (D) ( D) 0Nr iii P ND PD = = ∑ [14];

$$w = \left(\frac{4}{3}\pi N_T \rho\right)\left(\sum_i r_i^3 P_i\right) \tag{5}$$

where is the dust particle density assumed to 2.6 gm/cm3 , and the value of 4 33 T iii w N rP π ρ □ □□ □ = □ □□ □ □ □□ □ ∑ has been inferred from the work of Ghobrial [18] who measured particle size distribution for four dust storm events in Khartoum (Sudan). Based on various particle diameter distributions, Goldhrish [14] calculated the mean dust probability and found that 4 3 3 T iii w N rP π ρ □ □□ □ = □ □□ □ □ □□ □ ∑ is 3.48×10-5 (mm)3. Substituting these values into equation (5), it can be shown that the mean dust mass loading (gm/m3) is;

$$w = 3.79\times10^{-7} N_T \tag{6}$$

Wang et al. [17], using radar data over the Taklimakan desert, also showed that mass concentration M (μg/m$^3$) of dust could be expressed in term of radar reflectivity in form of Z-M relationship given in equation (7);

$$Z = AM^b \tag{7}$$

where A and b are constants whose values are 22,988.3 and 1.006 for a floating dust. Equations 6 and 7 can be combined to find the relationship between radar reflectivity Z and dust total density 7 3.79 10 w NT − = × by by adjusting the equation to have the same unit and noting that dust mass loading and dust mass concentration are the same, accordingly dust total density 7 3.79 10 w NT − = × can be expressed as;

$$N_T = \frac{\left(\frac{Z}{A}\right)^{1/b}}{3.79\times10^{-7}} \tag{8}$$

Finally, we obtained the visibility, Vx (km) from the expression in equation 9 according to Goldhrish [14]. Equation 9 relates the visibility with particle density 7 w N 3.79 10 T − = × and particle radius r, which allows radar estimation of dust profile. Vertical profile of dust allows the forecasters to make accurate forecast about dust episode by knowing the dust thickness at each layer in the atmosphere. This method can be incorporated into radar computer algorithm which will gives final output of dust profile.

$$\mathrm{Vx} = \frac{5.51\times10^{-4}}{N_T r^2} \tag{9}$$

An average value for particle size diameter of 0.0005 mm [19] has been used in consistency with mean dust probability over West Africa.

Visibility records usually made by observers at meteorological stations are based on visual inspection and are quite subject to the personal judgment of the observer and are limited to few vertical distances in meters. However, it can be used to the determine presence of dust load in the atmosphere. So in this paper, we have explored the use of radar reflectivity data to determine visibility and compare results with those "observations".

## Ground-based visibility, TOMS and Aqua terra AOD

Ground-based visibility data of year 2014 on daily basis, corresponding to period of radar data, were obtained from the archive of OGIMET SYNOP (https://www.ogimet.com/) over Akure. OGIMET SYNOP is a summary of daily weather for several countries of the world recorded in World Meteorological Organization (WMO) international code format. Apart from dust, several other atmospheric constituents may be attributed to a reduction in visibility such as heavy rainfall and fog. However, during the dry season over West Africa, poor visibility is majorly caused by dust incursion. Thus, the focus of the study shall be on the dry period when there was prevailing dust circulation in the atmosphere. Ozone Monitoring Instrument (OMI) on aboard the NASA Earth Observing System (EOS) Aura satellite also provides a measure of atmospheric dust in form of UV absorbing aerosol index (UV_AI). OMI data was designed to continue the long-term records of Total Ozone Mapping Spectrometer (TOMS). Kroon et al. [20] compared TOMS and OMI data products and found that up to 99% correlation exists between the two datasets and therefore complementary. UV_AI value could range between 0 and 6. Higher values of 3 and above indicate high dust concentrations in the atmosphere [21]. Moderate Resolution Imaging Spectroradiometer (MODIS) is an instrument on board of the Terra (EOS AM) and Aqua (EOS PM) satellites. Aerosol Optical Depth (AOD 550 nm) from aqua terra is another index that indicates the presence of dust in the atmosphere. Details description of MODIS AOD which include spatial resolution and retrieval error estimate can be found in Ridley et al. [22]. Both UV_IA and AOD 550 nm level 3 data were obtained from NASA gridded data interface (Giovanni https://giovanni.gsfc.nasa.gov/giovanni/) at daily time resolution and extracted for the study location.

## Results and Discussion

### Visibility observation

Horizontal visibility range (visual distance from the observer) has a direct relationship with the amount of particulate matters in the atmosphere. Anuforom et al. [6] categorized amount of dust in the atmosphere based on visibility range as Thick dust occurrence (THD) when visibility is ≤ 1,000 m, Light dust haze when visibility is >1,000 m and visibility ≤5, 000 m and clear atmosphere when visibility is > 5000 m. This categorization, which has been used also by other researchers such as Goudie et al. [15] and Engelstaedter et al. [23], applies only during the dry season when atmospheric dust accounts for almost all cases of turbidity in the atmosphere. In Table 2, daily frequency of occurrence of visibility is presented which showed that THD occurred only in January four times and once in February. However, LHD occurrence was more frequent in the month of January, February, August October and December. Since thick dust occurrence over Akure is very rare in August and October, only January, February, March and December poor visibility is attributable to dust occurrence. The total number of time when both THD and LHD occurred in January and December was 39 days out of 61 days with January as the haziest month of the year, having a mean visibility range of about 4 km. During those times, frequent flight delay and cancelation could occur with attendant loss of productive time and income. It should be noted that the visibility observation present here does not include the profile of atmospheric dust, as visual observations cannot sufficiently estimate dust profile. Dust accumulation during the dry season occurs at such height above the ground that visual observation might not adequately capture for recording. Due to atmospheric mixing, accumulated dust could descend rapidly within short time resulting into visibility deterioration. This situation usually is unpredictable using visual observation. However, radar profile measurements would capture dust accumulation above the ground, thus making occurrence of dust prediction possible and increase the reliability of ground observation especially for flight operations.

## Radar measurement of visibility

Based on equation 9, radar-derived visibility was obtained as shown in Figure 3 (upper panel). This figure illustrates the time evolution of dust occurrence during the course of a day on January 1, 2014. It also showed the profile of visibility between the ground and a range of about 4 km. Visibility on this day varies between from 8 km close to the surface, to 12 km at an altitude of about 1000 m. It is clear that visibility was rather poor in the morning hours recording about 8 km but improved during the afternoon hours to about 10 km and later became poor in the evening hours. This was also shown

**Table 2:** Visibility categorization based on frequency of occurrence using the daily data of year 2015.

| Months | 100-1000 (m) | 1001 -5000 (m) | 5001 (m) and above | Total | Mean (km) |
|---|---|---|---|---|---|
| January | 4 | 21 | 6 | 31 | 4.03 |
| February | 1 | 7 | 20 | 28 | 7.90 |
| March | 0 | 6 | 25 | 31 | 9.00 |
| April | 0 | 0 | 30 | 30 | 12.3 |
| May | 0 | 0 | 31 | 31 | 12.9 |
| June | 0 | 0 | 30 | 30 | 12.1 |
| July | 0 | 0 | 31 | 31 | 10.5 |
| August | 0 | 4 | 27 | 31 | 9.20 |
| September | 0 | 0 | 30 | 30 | 10.8 |
| October | 0 | 1 | 30 | 31 | 10.7 |
| November | 0 | 0 | 30 | 30 | 11.1 |
| December | 0 | 14 | 17 | 31 | 6.82 |

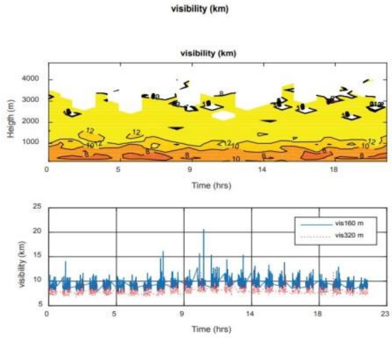


**Figure 3:** Visibility as estimated from radar reflectivity. Upper panel shows the diurnal variation of visibility profile while the lower panel indicates visibility at the two lowest radar range of 160 m and 320 m.

signal obtained after the initial signals sent out by the radar hit certain object (in the case dust particles) and scattered back to radar receivers at the base station. The scattered signal is a direct function of dust load in the atmosphere. So when many dusts are present in the atmosphere more signals is scattered and reflectivity is high. This relationship is explored here and we found that it has a very good correlation with observed visibility from observers' record as shall be shown later.

values are 22,988.3 and 1.006 for a floating dust. Equations 6 and 7 can be combined to find the relationship between radar reflectivity Z and dust total density 7 3.79 10 w NT − = × by by adjusting the equation to have the same unit and noting that dust mass loading and dust mass concentration are the same, accordingly dust total density 7 3.79 10 w NT − = × can be expressed as;

utilize the unused land in developing countries. The expansion of agriculture output caused abundant supply of unused land to be brought under cultivation. However, in most of the African countries such as Mozambique, Tanzania and Zambia, there are only 12 percent of arable land is actually been cultivated. The African Union (AU) has appealed to the governments to allocate 10 percent of their total spending to agriculture, but unfortunately only four or five countries have successfully reach that target. Obviously, developing countries do not have enough money to develop the unused land. It is a waste for just leave a huge area of arable land empty without any plantation. Thus, the offer by foreign investors to develop agricultural land is very attractive to developing countries.

always plays an essential role in the economy of every country. Not only because of it tends to provide foods for the entire population of a country but agriculture helps to connects and interacts with all the related industries of that country. A country is usually believed to be a social, political and economically stable nation if the agricultural sector is very stable. However, people in developing countries who are depend on agriculture for their living are always much poorer than those who work in other sectors of the economy. And generally those who involve in agriculture sector are always represents a significant share of the total number of poor people in the countries where they live. Hence, there is a need to improve agriculture industry.

Based on the standard of the "one-dollar-a-day threshold", there are 1.2 billion poor people in developing countries. And among these peoples, there are 780 million of them facing chronic hunger, which means that their daily intake of calories is not enough for them to live healthy and productive lives. Besides, there are millions more suffer from specific nutritional insufficiency of one form or another. Most of the world's hungry live in countries which are categorized as low-income and food-deficit nation. They are located mainly in the developing world and more than half of them are in Africa. These countries do not produce enough food to meet the demand of the citizens and they may not have enough foreign exchange to replace the shortfall by purchasing foods on the international market. This kind of situation getting serious especially when they are facing with loss of crops and livestock that caused by natural disaster or extremely high food prices on the international market. In order to feed people better, agriculture must strengthen its conservation goals by adding assortment to the food chain and by restoring the ecosystems.

Agriculture sector can reduce hunger as it ensures the food security of developing countries. The drive toward food security has seems to be slowed in recent years. The growth rate of agricultural production is declining, the world grain reserves have shrink to record lows, the commitments of aid to agricultural development have decreased as well and thus it boosting the demand for imported grain. This obviously opposed to the current situation of developing countries because their population is expanding. Food production is directly related to the daily life of human being. Food security is an immediate and future main concern for all developing countries. A stable agricultural industry plays an important role to ensure the food security of a country. Food security is considered as one of the basic requirements of any nation. None of the nation that consists of huge amount of hungry people can grow efficiently with a stable agricultural base because hungry people can do nothing towards helping to develop their country. Food security prevents starvation which often been considered as one of the serious problems that being faced by the small developing countries.

Furthermore, agriculture also ensures economic growth of developing countries. Agriculture is a fundamental source of income for developing nation that exists on this globe. Not only because of it provides food for our daily life, but mostly all the industries in the country depend on agriculture both directly and indirectly. The high rates of economic growth are basically linked with the rapid expansion of agricultural output. In fact, the economy of several West African countries is primarily maintained by agriculture sector. Most of them depend on agriculture for their export trade to boost the incomes of the country. Agricultural products are their main foreign exchange earner which contributes about 75 percent of their total export commodities. The exports of agriculture products create additional economic activity that ripples through the domestic economy. Besides, agriculture contributes between 40 to 60 percent of the total GDP of most of the African countries.

In conclusion, it is crucial to develop the agriculture sector not only in the developing countries but every country in the globe. A very low GDP and widespread chronic under nutrition are generally because of the underdeveloped of agriculture sector. Citizens cannot get enough their basic needs for their daily life. Therefore, economic progress in the agricultural industry is very important to boosting the incomes and increasing food supplies of the poor. Agricultural sector can only be further develop if and only if everyone in the society willing to take the responsibility to sustain a society that have sufficient food supply for our future generation. This is an issue that related to the whole society and efficient action must to be taken from now on.

Forestry management involves maintaining windbreaks between fields and roads, using coverage to prevent erosion, and also as protection for the home site and barns. This knowledge helps prevent many physical problems associated with the weather elements.

Health administration can be related to actual medical work in rehabilitation centers for injured farmers or implemented in a private manner on the farm where emergency assistance is likely to be over an hour away for many ranches.

Human resource management knowledge is important to people who employ others or work in a managerial position on large beef, dairy, or crop farms. Possessing leadership skills is important if one if responsible for organizing employees' work duties, and implementing the necessary changes daily plans requires.

Employment as a manager in charge of supply-chain management may involve procuring commodities for a farm, or working at a public retail business selling agriculture equipment. Public relations is important in both situations as one would be required to deal with people on a one-to-one basis ordering and selling goods.

As you can see, a Master of Business degree with an agriculture specialty has many applications in the job market. Potential employees would be well-equipped to obtain employment in professional fields as well as farm positions. Information is going to be a key ingredient in determining one's employment position in the years to come. "Information society theorists look forward to the rise of a new service class of knowledge workers, men and women whose work is characterized by high levels of technical skill and theoretical knowledge, and which correspondingly demands long periods of education and training" (Webster et al., 2004, p. 112). Higher education is going to be required in many fields. Webster et al. (2004) explains that "knowledge, according to information society theorists, is progressively supposed to affect work in two ways. One is the upgrading of the knowledge content of existing work, in the sense that the new technology adds rather than subtracts from the skill of workers. The other is the creation and expansion of new work in the knowledge sector, such that information workers come to predominate in the economy" (p. 111). The new information society is upon us and if one is to be successful, one needs to be well educated. Rost (1993) also concurs that "leadership is one of the concepts and practices that will be transformed as Western societies move from an industrial to a postindustrial paradigm" (p. 127). Knowledge workers are the new employees of the current society.