FROM PARADOX TO REALITY: UNFOLDING THE DISCIPLINE OF SOIL PHYSICS IN SOIL SCIENCE.

BY
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MOVING LOCAL KNOWLEDGE OUT OF THE LABORATORY
Meanwhile, I as a soil physicist, continue to attempt to impose order in the field by focusing on local knowledge/practices, struggles for authority, and natural strategies and technical devices for moving techno-scientific knowledge as coherent structures in the turbulent flow of the soil physics. ……………………………………….Adapted from Turbull.

PREAMBLE:

In trying to contextualize his trajectory in Agriculture in this University, the first inaugural lecturer from the Faculty of Agriculture of this University, Professor Ignatius Ugwudike Obi, spent a lot of time to tell us or those who may pretend not to know, what he had spent about thirty-five years in this University doing. He was ***ab intio*** interested in Agriculture. To keep the records straight, I was never aspiring to be trained as a Soil Scientist. When I was teaching Chemistry and Biology at Boy's High School, Nkwerre, in Imo State, I had been advised that instead of trying to rectify an anomaly in my ordinary level Physics, which I did not have, to enable me be admitted to read Pharmacy at the then University of Ife, Ile-Ife, I should go to the

University to pursue a course in Plant/Soil Science with major in Plant Breeding up to the Ph.D level. So I entered this University in 1972 to read Plant/Soil Science with interest in Crop Science. As should be expected of someone who had already obtained a Division One in the School Certificate Examination in 1964, from Ibo National High School, Aba, three papers and a General Studies paper at the Cambridge Higher School Certificate Examination at Hope Waddell Training Institute, Calabar in 1966, and three papers at the London General Certificate of Education, Advanced Level Examination in 1967, I made the best result in the Department of Plant/Soil Science in 1975. The Head of Department of Crop Science then, did not quite like me and my performance and so did not recommend me for interview as a Junior Research Fellow (Graduate Assistant) in the Department of Crop Science. I was advised by the late Professor F.O.C. Ezedinma, my mentor, to go to his friend at Umudike to plead for a job in Soil Conservation. As I left Professor Ezedinma’s office to go to Umudike, I met my teacher, Professor D.M. Ekpete, the ultimate soil scientist, who was then the Acting Dean of the Faculty of Agriculture. He inquired if I was to attend the interview in two day’s time. When I replied that I was not recommended, he was visibly angry and asked if I wanted to be a Soil Scientist. When my answer was positive, he was very happy to inform the Controller of Personnel Services then, Mr. Nduka Eya, that he was sending another person to make the number of people for the interview as Junior Research Fellows in Soil Science to two. Mr. Vice Chancellor Sir, this was how my training as a Soil Scientist began.

After the compulsory one year in the Department of Soil Science, University of Nigeria, Nsukka (1976/77), I traveled to Cornell University, Ithaca, New York, to do an M.Sc degree in Environmental Quality in 1980 and a Ph.D degree in Soil Physics and Conservation in 1981. In going to Cornell University, I was following the traditions of Professor Bede Okigbo, Professor Mike Echeruo, Professor T.O.C. Ndubizu, among others, to explore the intricacies of the unfolding Universe of Soil Physics. Because of lack of a suitable program in Soil Physics at Cornell University, for someone like me, I applied for and got a Scholarship to study for one year under Dr. (now Professor) Ratan Lal at the International Institute of Tropical Agriculture, Ibadan, during the 1980/81. This one year provided me with the experience I needed to do research in the rudiments of

Physics as applied to Soils and I made good use of this opportunity. Ladies and Gentlemen, this is how someone who was deficient in ordinary level Physics has come to teach Agricultural Physics (Mechanics and Heat) to first year students in Agriculture. This is how a novice in Physics has today about 211 refereed and internationally published papers in Soil Physics and Conservation.

Mr. Vice Chancellor Sir, this very brief summary of my last days in this University as an undergraduate in the Department of Crop Science taught me a few lessons in human relations. Firstly, that I do not have to accept the face of someone as an index of his or her consummate reality. Secondly, that I do have to be very wary about people who I may regard as my true “friends , because everyone has his or her motive for associating with you.” Thirdly, that only God rewards those who truly and diligently trust and obey him. **Smiling Faces Do Not Always Tell A Lot About The Evils That Lie Within.**

This my inaugural lecture will be approached in the following order: firstly, I will give an overview of what the soil is, from the classical to the edaphological definition; secondly, I will relate the soil to the environment and ecosystems; thirdly, I will try to articulate the vistas of a soil scientist in the changing terrain of soil science and fourthly, I will conclude by highlighting my research works in soil science, which made this University pronounce me a Professor of Soil Physics and Conservation in 1992 (that is four year’s late) but announced it in 1999 and which also enabled me to win the Vice Chancellor’s Research Leadership Prize in Soil Science in this University in the year 2003/2004.

WHAT IS SOIL SCIENCE?

One of the earliest definitions of soil science is the outer cover of the earth's crust. This definition does not encapsulate the origin and functions of soils. Traditionally, the soil is regarded as the outer layer of the earth's crust that provides ancourage and nutrition for crops and plants. This is the edaphological definition. The Civil Engineer may regard what is traditionally refereed to as the soil as the outer crust that must be removed before further investigation of the materials (laterites) that must be needed for building foundations. The Engineering Geologist is of the view that a soil does not exist *per se* and what exists and is relevant is the mineral soil or rock in which crude oil is deposited and should be explored. The Geographer sees soils as the materials that are formed as a result of litho-logic discontinuities on the surface of the earth. Since Soil Scientists, together with Agricultural Engineers, deal with the surface outer crusts of the earth, their definition of soil science will be sufficient for our purposes in this lecture. The soil should be defined as the medium on which crops grow, and should be managed to optimize the nutrient status, the physical and biological qualities and the engineering properties of the medium for good plant growth and development. So courses like Soils and Agro-Physics, Soil Chemistry and Mineralogy, Soil

Biology, Micro-Biology and Biochemistry, Soil Morphology and Micro-morphology, Soils and Environment, Soil Degradation and Rehabilitation, Nutrient Management in Soils, Humus in Soil Conservation, Irrigation and Soil Drainage, Agro-forestry, Microcomputer Applications in Water Resources Engineering, Use of Isotope Techniques in Soil Research and Plant Nutrition, Soil Science, Plant Production and Ecology, Soil Mineralogy, etc., have gained attention in our discuss of soil science. The areas of soil science research and training have spanned Soil Geography, Mapping and Evaluation, Soil Systems and Management, Experiments in Oil-Contaminated Soils, Mineralization of Hydrocarbon and Gas Dynamics in Soils, Integrated Resource Management & Landscape Modification for Environment Protection and Tomography of Soil-Water-Root Processes. So far I have deliberately not mentioned Agriculture as a main focus of our study of soils. This is deliberate and obvious and it is an aspect of study that I have focused my attention in the past 30 years.

On Sunday, 23rd September, 2007, as I was stepping into the Christ Church Chapel, and as the Christ Church Chapel Sunday School was going on, the authority who delivered the 23rd Inaugural Lecture of this University approached me and suggested that one of the reasons why we do not have the right number and caliber of students is that we allowed Soil Science to be in the Faculty of Agriculture. This person is an authority in curriculum development in Science Education, Professor (Mrs.) Eunice A.C. Okeke. I agreed with her and informed her that the previous year we had only three students from JAMB examination and one from Direct Entry option. Soil Science is ideally a Biosphere study and should belong to the Faculty of Biological Sciences or Faculty of Earth Sciences (if this exists). At the University of Wageningen, Holland, there is a Department of Soil Science and Plant Nutrition and another Department of Soils and Earth Sciences. These two Departments do not conflict with each other and the lecturers teach what is relevant for the society and man.

SOILS, ECOSYSTEMS AND ENVIRONMENT

The ecosystem is of immense importance in our study of soils and soil science that it requires a thorough explanation. The ecosystem can be small catchments, pieces of land, region, or water bodies. It can be studied from purely physical, chemical or biological point of view. It may constitute dry-land areas, tropical areas, boreal areas, etc. Toxic metals may be associated with their studies, as in Geo-medicine, which may form part that deals with Environmental Health. This is the main focus of research in the Universities of Scandinavian countries. Essentially, they try to relate certain diseases of man (and woman) to the status of some heavy metals in the environment. Diseases like Grass Tetany (caused by Magnesium Deficiency), White Muscle Disease (caused by Selenium deficiency), Dental Carriers (caused by Zinc deficiency), Dental Decay (caused by deficiency of Fluorine), among others, are identified and treated. This is essentially Geo-medicine. **Malnutrition they say, starts from the Soil.** The only remedy to some nutritional problems of people is to correct the nutritional imbalance in soils.

The Obukpa farmers, who use this University’s sewage wastes and effluents, have been unable to tackle the problem of endemic goiter, prevalent in their community. Dr. (Mrs.) Joy U. Nwamarah, who made a survey of this disease, suggested that the soil may be the source of the iodine deficiency in the food of these Obukpa people. We may need to study this further, and advise on ways to overcome this problem. This is the aspect of etiology in soil science (Nwamarah, 2006).

Research in Soil Science can vary from Ecosystems to Global Scales. At the Global Scales, the researcher can only make some meaningful generalizations about some qualities of the soil. Universities in North America, among others, have mapped the soils of U.S.A. to the minutest details and assessed them on the basis of their potential for utility. Hence, as a general rule, good soils should be reserved for agriculture and bad soils for construction works. Some soils that may be regarded as bad, especially soils that are impacted by water resources, are suggested to be used for growing paddy rice.

In the regions of south-east Tompkins County, Ithaca, New York, it was easy for me, doing a class assignment, to predict precisely the rate and time soil erosion by water would occur. After about four weeks of my prediction, devastating soil erosion occurred there and destroyed many things. My prediction was based on the Universal Soil Loss Equation (USLE) which was produced by Americans and not the Red Indians (Mbagwu, 1977).

Sometime in 1990 I was invited to contribute a chapter in a book on Selenium in the Environment. My chapter dealt with the speciation of selenium and the different analytical tools used to select the different mechanisms of selenium in the ecosystem. I discussed the etiology of selenium-responsive diseases, the biochemical and geological cycling of Selenium, its world-wide distribution, and the factors controlling its fate and transport within and between major environmental media-presenting a global assessment of selenium's complex environmental behavior. The book covered the transformation, transport, and toxicity of Selenium, with emphasis on its role in plant and animal health. I analyzed its two endemic diseases, and their relationship to Selenium adsorption, volatilization, and speciation in different types of soils. I also assessed the ecological risk of Selenium poisoning (Mbagwu, 1995).

In 1997, a former student of our Department returned from the Iowa State University, Ames, Iowa State, to do his Ph.D field work under my supervision. His interest was on heavy metal movement in sewage sludge-amended soil. We used the lowest site on this campus, where sewage sludge had been discharged for about 40 years, for his study. Using an ingenious analytical technique he showed that Cd, Hg, Pd, Zn, Cu and Ni moved from the topsoil to the sub-surface horizons. These are heavy metals that at high concentrations can be very injurious to man and animals. This man, Dr. Monday O. Mbila, completed his Ph.D in the year 2000, and is currently a confirmed (Tenor-tracked) Associate Professor of Soils and Land Use Systems Engineering at the Technical University, Alabama, U.S.A. (Mbila, 2000).

In 1994 a Ph.D student of mine worked on “Bioremediation of an Alfisol contaminated with Spent-Lubricating Oil and treated with organic wastes.” This student also got a Common Wealth Scholarship and traveled to the University of Stirling, U.K., to do the micro-morphological aspects of his work. At the presentation of his seminar, many students and staff were trilled and convinced that in dealing with bioremediation of soils, we can also look at the fractal dimension (mathematics) of the distribution of pore spaces and mean-weight diameter of water-stable aggregates (Adesodun, 1997).

Another Ph.D student of mine worked on Phyto-remediation of an Ultisol contaminated with Spent-Lubricating Oil. (Udom, 2007). He graduated this year. A third Ph.D student of mine is looking at the productivity of an Ultisol at Abakiliki contaminated with Spent-Lubricating Oil and Bioremediated with Rice Mill (Organic) Wastes. A fourth student is studying the use of plant waste materials to Bio-remediate Spent-Lubricating Oil-Contaminated Ultisol at Nsukka (Ahamefule, 2008). In all these studies the students try to identify and isolate bacteria responsible for degrading hydrocarbons in the oils and soils. We are not able to give them names but we know they exist.

My first Ph.D student, who incidentally read my citation this afternoon, Prof. C.A. Igwe, compared two erosion prediction models, the USLE and SLEMSA models, for their ability to predict erosion in some parts of southeastern Nigeria. He concluded that none of the two models was very effective and used the principles involved in their development to suggest a more elegant model for more accurate predictions of soil erosion in the tropics. This Ph.D work won the Vice Chancellor’s first Prize in 1994 (Igwe, 1993).

In 1997 also, I got a scholarship for a Ph.D student of mine of travel to Innsbruck, Austria, for her field work.

She was interested in relating aggregate stability of tropical soils to some microbial systems. From her studies, which were supervised by Professor Henri Insam, a Soil Microbiologist, she has published over 8 papers, the latest so far being **“Biolog Substrate Utilization Assay of the Rhizosphere of Cassava and Forested Ecosystems.”** Right now she is a Senior Lecturer and teaching at the Michael Okpara University of Agriculture, Umudike, and is married with children (Eneje, 2003).

In 1995 another Ph.D student of mine studied the pollution potential of the use of four organic (animal) wastes on an Abakiliki Ultisol. He found that each of the organic wastes he used had serious pollution potential, especially since they are from animal sources. He used the Biological Oxygen Demand (BOD) and the Chemical Oxygen Demand (COD) to assess their pollution potential. At present he is a Senior Lecturer and acting Head of the Department of Soil Science & Environment at Ebonyi State University, Abakiliki (Mbah, 1997).

In 1996, a Ph.D student of mine studied the use of organic wastes to grow cassava at the Nsukka plains. His work produced interesting results that showed that even though cassava can tolerate very infertile soils, it can do better if grown on well fertilized ones. At present he is teaching at Delta State University, Asaba Campus and is a Lecturer I (Nnaji, 2003).

What else can I say? A female Ph.D student of mine is right now on a scholarship at IITA studying the other contributions of cover crops to soil fertility. She wants to find the other roles of leguminous cover crops on soils apart from contributing nitrogen to the associated crops. Another Ph.D student of mine is looking at the relationship between aggregate stability of tropical soils treated with pesticides (in particular, herbicides) and their ability to adsorb humic substances. Our Ph.D student is trying to identify some early-warning properties of some Nigerian soils that could be used to suggest when dangers appear to be imminent. My other Ph.D student verified in the field the contributions of carbohydrates, humic acids, fulvic acids and humin to aggregate stability. Using the Principal Component Analysis he showed that humic acids more than other organic matter pools influenced aggregate stability most. He has been teaching at the Michael Okpara University of Agriculture, Umudike.

SOILS IN THE SERVICE OF MAN

Why should our students study soil science? Many students of soil science fail to link their studies with the practical realities of the areas of emphasis. Among the many attributes of soil's study is its relationship with the physical environment. We should know enough soil science to be able to counteract the many spurious claims of pseudo-soil scientists who know only little about the subject matter. In 1985, a celebrated Geomorphologist, Professor G.E.K.

Oformata, gave an inaugural lecture on **"Soil Erosion in Nigeria: The Views of a Geomorphologist".** This lecture had certain misgivings, one of them being that soil erosion did not correlate with human activity. Hence the conclusion from that lecture was that human beings do not cause erosion. I stand here today to say that this conclusion is false. Soil erosion by water is initiated and executed by human beings. No amount of good statistics can prove this wrong. Ordinary statistical correlations by well-trained analysts cannot disprove this and I think that if human beings take cattle and sheep to feed on a plain, the consequence of this effect is attributable to the humans and not to the cattle or sheep.

There are other very minor areas in which we should be concerned about the uses of our knowledge of soils. For example, what is the reason for the manifestation of the endemic goiter among the Obukpa people? Why do infants and little children often manifest the incidence of teeth decay and dental carriers? Are there any relationships between soil properties and the manifestation of some diseases? What should be the response of soil scientists to the etiology of selenium-responsive diseases? What other diseases of man and woman are related to soil science? Answers to these questions need urgent attention and we invite you to come and assist in providing such answers.

When we were in the primary and secondary schools, we were introduced to the Neolithic man. He tried his best to eke out a living from the land. His implements were obscure but he did his best with them. Where are the Neolithic men these days? Every body is talking about mechanization now as if it is the only way to increase our food output. In Italy, Germany, parts of U.S.A. and Europe, farmers are going back to the basics again. In Africa I doubt if we ever left the Neolithic culture in our agricultural practices. Going back to some basics is the in-thing now. Are we not being left behind? The essence of good soil husbandry is to manage the soil so that generations yet unborn may benefit from it. Over mechanization is not good for our fragile soils. It causes degradation of the soil structure and so should be avoided.

Talking about degraded soil structure, we have focused our attention on it for sometime now. In the context of this lecture, land degradation is the temporary or permanent lowering of the productive capacity of the land caused by overgrazing, deforestation, inappropriate agricultural practices, over exploitation of fuel wood leading to desertification and other man-induced activities (FAO, 1992). All processes of land degradation are grouped into six classes: water erosion, wind erosion, soil fertility decline, salinization, water-logging, and lowering of the water table.

What is soil structure? Any person may attempt a definition but it means, in the plain language, the arrangement of soil particles to form peds. Kay (1990) defined soil structure as the spatial heterogeneity and temporary variability of the different components or properties of the soil. Soil structure could be managed through cropping practices, tillage, traffic control, and drainage and use of soil amendments. A soil with a good ped or structure should form a good soil tilth and a good soil tilth is what every land user desires for crop production. The merits of good soil tilth are encapsulated in my studies on saturated hydraulic conductivity in the Nsukka plains published in Geoderma in 1985. In this study I showed that unlike the conventional acceptance, the relationship between saturated hydraulic conductivity and pore size distribution could be described best with the curvilinear relationship:

$$K(\theta) = 0.07e^{0.08(Pe)}$$

where $K(\theta)$ is the saturated hydraulic conductivity and Pe is the macro porosity.

Blair and Crocker (2000) studied the effects of crop rotations, including legumes and fallows, on structural stability, unsaturated hydraulic conductivity and the concentration of different carbon fractions on black and red clay soil. Aggregate stability was reduced as a result of cropping and cultivation for both soil types.

However, aggregate stability improved for both rotation and continuous cropping treatments compared with the long fallow. Scott et al. (1987) found that certain grasses and legumes can be established under corn to provide adequate ground cover over winter to reduce soil erosion significantly and also, to improve soil aggregation.

The attempt to suitably relate saturated hydraulic conductivity to pore size distribution in the soils of the Nsukka plains has been verified by some students at the Federal University of Technology, Owerri (FUTO), among other Universities. We also tried to verify the relationships between other physical variables (notably those related to aggregate stability) and the major soil properties. The relationships so far suggested are statistically-based, which is a limitation to their universal applicability, but until good, process-based, mathematical relationships are available, I suggest that we make use of these statistical ones.

Mr. Vice Chancellor Sir, in the year 2003 I was invited by the organizers of the College on Soil Physics, the Abdus Salam International Centre for Theoretical Physics, Trieste, Italy, to contribute one or two chapters to a publication on Twenty Years of Soil Physics Studies at ICTP. Only one other student of mine, Prof. F.K. Salako, was similarly invited from Nigeria for such a task. In my contributions titled **"Aggregate Stability and Soil Degradation in the**

Tropics" and **"Evaluation of Soil Structural Modifications in the Mediterrenean Region"** I argued that the low organic matter contents of the soils of the tropics were responsible for the manifestation of soil structural collapse in the tropics. Also because of constant use, the soils of the Mediterranean region were easily degraded as a result of low organic matter content (Mbagwu, 2003a, 2003b; Salako, 2003a, 2003b).

So far we have not solved all the problems in Soil Science. In their write-up on **"Some Aspects of the Development of Soil Physics in Central and Eastern Europe and the Impact of a Totalitarian Ideology upon it"** Professors M. Kutílek and V. Novάk, argued that the rise in soil physics in central Europe was associated with the practical needs of agriculture in the second half of the nineteenth century. Whether the soil samples were tested in the laboratory or the field is immaterial right now, but let it be known that between 1950 and 1960, four essential norms of the natural sciences were formulated as: universalism, communality, disinterestedness and organized skepticism. However, the philosophical schools of postmodernism relativized these norms, and postulated that the links between society and science were loosened. They accepted that the results of scientific activities were described as subject to questioning. Who should ask these questions? Also where the methodologies have been spelt out, what are the reasons for such questions and who should be asking them? (Kutílek and Novάk, 1997).

THE INTERNATIONAL SOIL REMEDIATION RESEARCH CENTRE.

An international task force consisting of soil scientists, geochemists, biologists, and ecologists is being asked to look into the feasibility of establishing an International Soil Remediation Research Centre, focused on remediation of chemically-degraded soils. It was proposed by Professor Dr. Adriano that polluted soils may lead to degrading of the quality of the food chain, surface water and ground water. This centre is also planned to educate and train students, scientists, educators, and regulators on the science and technology of soil remediation and their applications to solving real world problems. In addition the centre will foster cooperation between industry, governments and academia in remediation of contaminated soils (ISSS, 1993).

In Nigeria we have many sources of soil contamination. Some of our students had to travel outside Nigeria to study the mechanics and processes of remediation of the soil. One boy who made a First Class Honours Degree in our Department in 1990 had to travel to Britain to do the M.Sc. degree in Soil Remediation. In Nigeria, we have some consequences of land misuse as oil spillage and pollution, stone-harvesting on soils, heaps of refuse and wastes, biological wastes, thrashes of crops and trees, sewage sludge and effluents. This sewage sludge and effluents constitute an enormous source of wastes at the University of Nigeria, Nsukka. Obukpa farmers utilize them continuously to grow green vegetables during the dry season. Mrs. Felicia Mbagwu studied for her M.Ed. degree, the extent of health hazards associated with the use of these sewage sludge and effluents in food crop production. She found that they are not sources of heavy metals but that certain endemic microbiological diseases like typhoid fever, dysentery, entero-amoeba, etc. could be contacted via eating green leafy vegetables grown on the sewage sites (Mbagwu, 2000).

How do we reconcile the different methods available for bioremediation of these organic waste-associated diseases? There are very many ways but the best is to focus on the way these food chain-products are utilized and whether it is necessary to use them at all. After this, we suggest alternative ways of handling the food products. The best approach is to try and break the food chain-link that can cause any such disease and so, leave happily thereafter.

VISTAS IN BIOPHYSICAL REALITY

In trying to pink a topic for this lecture, I first of all chose **"Footprints on Soils, Reflections in Water"** but I quickly recollected that I came across this topic in 1977, (while I was doing research for my post-graduate studies) in the College of Agriculture Library, Cornell

University, Ithaca, New York. I discarded this topic and decided to ramble on my vistas in the biophysical reality of soil science. The idea of Biophysical Reality came from my interactions with the Abdus Salam International Centre for Theoretical Physics, Trieste, Italy. In its library there is a rare books section and I was there cross-checking the rare book deposited there on Solid State Physics written by Professor A.O.E. Animalu of our Department of Physics. While there I saw a book with the title **"Vistas in Physical Reality"**. So I thought that even if it did not make any sense I will incorporate it in this title. After all we have been told here that **"Life does not depend on the liver"** without the presenter making any attempt to tell us on what organ life depended.

Mr. Vice Chancellor Sir, in your first convocation in this University, I was invited to accept the prize tagged Vice Chancellor's Research Leadership Prize for my activities in Postgraduate Studies. Essentially my works in this University, which culminated in the award of this prize, started in 1986 at the Centro di Physica del Suolo, Firenze, Italia. There I worked with Italian-trained soil physicists and chemists on the role of some biological agents in soil aggregate stability. We published many peer-reviewed papers from this work. I think that by now there are more than 100 of such papers on aggregate stability of soils. It was here that I was practically introduced to the three different pools of organic matter: the humic substances (i.e.

humic acids, fulvic acids and humin). We extracted the humic and fulvic acids in Firenze but latter in 1995/96, with the help of another fellowship from Trieste I traveled to Portici, Napoli, and continued this study with Professor Alessandro Piccolo, a soil chemist. We extracted humin and used it to relate to aggregate stability (Mbagwu and Piccolo, 1998). We established several relationships between aggregate stability and soil properties. Some of these relationships related the mean-weight diameter of water-stable aggregates (MWD) to soil physical, chemical and mineralogical properties in multiple regression ways. Three examples are:

For Chemical Properties: MWD = 1.61(FeO) + 0.13 (MgO) – 2.07 (R^2 = 0.750;

SE = 3.503)

For Physical Properties: MWD = 1.303 – 0.797 (SC) – 0.0012 $(SC)^2$ (R^2 =

0.897; SE = 2.359)

For Mineralogical Properties: MWD = 0.025 (chlorite) – 0.016 (muscovite) – 5.84

(R^2 = 0.530; SE = 4.08)

What we have not done yet is to relate the MWD of water-stable aggregates to all these three properties simultaneously. This will give us an idea of the class of properties which dominate the stability of soil aggregates.

We may try this by using the Principal Component Analysis (PCA), which is an orthogonal comparison of factors which influence aggregate stability most. In a study which Dr. B.E. Nwadialo and I did in 1991 (Nwadialo and Mbagwu, 1991), we saw that the orthogonal comparison of the different classes of properties showed that aggregate stability was influenced most by the mineralogical properties of soils. This paper was published in Soil Technology. The Component Defining Variables (CDV) was established by identifying those with the highest loadings on the variables in each axis of the factors. With this we did a multiple regression analysis and obtained the result as follows:

ASC = 0.91 – 0.876 (Chlorite) – 1.090 (Feldspar) – 0.235 (Muscovite) (R^2 = 0.673, S.E. = 4.03).
where ASC is Aggregated Silt + Clay, a micro-aggregation stability index, that is used to assess the potential of soils to disintegrate in water, that is a measure of aggregate stability (Nwadialo and Mbagwu, 1991).

We have also checked the stability of soil micro-aggregates from the North Central Italy amended with cattle feed-lot manure and subjected to up to 15 cycles of freezing and thawing. The aggregate stability was assessed with three indices, viz, the clay dispersion index, the rainfall stability index and the water stability index. Only one index, the clay dispersion index, actually reflected the destabilizing response of soils to cyclic freezing and thawing (Mbagwu, 1992).

Wetting and drying cycles are important environmental phenomena affecting aggregate stability of soils, especially in the temperate zone. We investigated its impact on the stability of aggregates of three soils from North Central Italy treated with cattle feedlot manure. The objective was to identify the level of organic matter in the soil that might make the impact of wetting and drying cycle effective as a soil-modifying mechanism. However, at the rates investigated, no organic matter level in the soil could achieve this. The mechanism of response to organic matter by the soils was linear for the sandy soil, parabolic for the loamy soil and negatively linear for the clay soil (Mbagwu, 1990). Additionally, the various amounts of organic matter in the soils could not be related to soil structural changes.

Another aspect of our studies is that related to soil microbial biomass. Soil microbial biomass has been used to study the beneficial and non-beneficial effects of different crop management systems at Nsukka, including cropped and forested ecosystems. Eneje et al. (2002) identified the effects of several of soil microbial biomass C to soil aggregate stability. Soil microbial biomass consists of 3-5% of soil organic matter. It is regarded as the active soil organic matter and is used as a measure of soil organic matter since total soil organic matter is non-responsive over a short period. Therefore, we can use soil microbial biomass to act as an early and sensitive indicator of the changes in soil organic matter. According to Adeboye et al. (2006), crop rotations do not necessarily influence the gross soil microbial biomass but may affect the physiologically distinct sub-component of the microbial biomass such as soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN) and water soluble organic carbon (WSOC). These authors also showed that the various rotations had predominance of fungi community, as indicated by their wide biomass C/N ratio, ranging from 9.2 to 20.9, and suggesting that fungi are mainly responsible for the decomposition of organic wastes in these soils. Actually, fungi are active decomposers of organic residues, so predominance of fungi may lead to higher mineralization and release of plant nutrients for improved growth of cereal plants.

EVALUATION OF SOME ENVIRONMENTAL FACTORS INFLUENCING THE STABILITY OF AGGREGATES OF SOME NIGERIAN SOILS

Mr. Vice Chancellor Sir, the stability of aggregates refers to the tendency of a soil to resist deformation due to applied forces (Burke et al., 1986). Soil aggregate stability although appearing to be a relatively simple concept, is in fact a complex soil property having significant inter-relationships with most of the recognized physical, chemical and biological processes of the soil as well as environmental factors such as climate (Utomo and Dexter, 1981). Because of these interrelationships in the field, it is not too surprising that there is some lack of agreement in the literature on the relative influences of many factors on aggregate formation and stability.

The entire dynamics of soil aggregate formation and degradation has been extensively studied and documented. The works of Tisdall and Oades (1982) and Emerson (1983) among others, are very detailed on the subject. However, many investigators have attempted to relate aggregate stability more closely to organic matter content (Tisdall and Oades, 1982; Mbagwu, 1989; Molope, 1987; Mbagwu and Piccolo, 1989; Kinsbursky et al., 1987; Mbagwu and Bazzoffi, 1988; Mbagwu, et al., 1991), influence of surfactants (Law et al., 1966; Letey, 1975; Mbagwu and Piccolo, 1989; Mbagwu et al., 1991), effect of wetting and drying cycles (Mbagwu and Bazzoffi, 1988; Utomo and Dexter, 1982; Harris et al., 1966 and Molope, 1987) and antecedent moisture content (Mbagwu and Bazzoffi, 1988; Gerard, 1987, Utomo and Dexter, 1982). The present evidence is that the contradictory conclusions being drawn concerning the effects of these factors on the stability of soil aggregates may not be unconnected with the multitude of methods used to evaluate aggregate stability (Bazzoffi and Mbagwu, 1986) or the difference in response of soils to different treatments (Molope, 1987; Mbagwu, 1989, and Mbagwu and Bazzoffi, 1988).

Influence of Organic Matter on Aggregate Formation and Stability

Soil organic matter consists of soluble and insoluble organic substances present in the soil which can pass through a 2 mm diameter sieve. They include living (microbes) and non-living (decayed plants, microbial and animal residues, plant and animal exudates, their metabolic products and the humus) substances (Piccolo, 1996). The role of organic matter in the formation and stability of soil aggregates has been investigated by many workers (Tisdall and Oades, 1982; Chaney and Swift, 1984; Hamblin and Davies, 1977; Hafez, 1974). The activity of root systems and soil fauna are considered the primary factors of aggregate formation (Baver, 1972). According to Russel (1973), soil aggregates arise as a result of aggregation of primary particles into secondary, larger particles by the cementing substances derived mostly from microbial slims and gums, soil animals, mycelia of fungi, root exudates and fine roots.

Various sources of organic matter which influence aggregate stability have been investigated (Aina and

Egolum, 1980). Bazzoffi and Mbagwu, (1988), and Mbagwu and Bazzoffi, (1989) reported works on the use of cattle feed lot manure as organic matter source for three soils in North Central Italy. Municipal sewage sludge, as organic matter source, has also been shown to enhance the stability of soil aggregates (Metzger and Yaron, 1987) although their capacity to do so was proved to be dependent on the physical and chemical properties of both the sludge and soils (Pagliai et al., 1981; Borchert, 1983). Agbim (1981) and Agbim (1985) also reported the potentials of cassava peels as a soil amendment.

There is however, some lack of agreement in the literature on the effect of organic matter on the water stability of soil aggregates. De Kimpe et al. (1982) and Coote and Ramsey (1983) did not find a significant correlation between organic matter levels in the soil and per cent water stable aggregates. Chaney and Swift (1984) and Clement (1975) however, indicated that significant positive correlations existed between total soil organic matter and percent of water stable aggregates. Further investigations have revealed significant correlations between specific constituents of organic matter and soil aggregate stability, indicating that certain fractions of organic matter are more active than others in influencing aggregate stability (Greenland, 1971; Hamblin and Davies, 1977; Chaney and Swift, 1984). One fact that is generally agreed by researchers is the indispensable contribution of living organisms in the stabilization of soil aggregates by organic matter. When organic matter was treated with mercuric chloride ($HgCl_3$) poison to eliminate soil microbes, it failed to show any effect on soil aggregation and stabilization compared to non-treated residues.

Organic matter is generally made up of two groups: the non-humic substances and the humic substances. The non-humic substances which comprise between 20 and 30 % organic matter, are made up of mainly carbohydrates, proteins, peptides and amino acids. The humic substances which make up 70-80 % of organic matter consist of humic acid, fulvic acid and humin (Tisdall and Oades, 1982; Chaney and Swift, 1986). Humic substances are formed in soils after prolonged decomposition of organic residues (Mbagwu, 1989; Piccolo and Mbagwu, 1989). This is why their action in stabilizing soil aggregates takes very long periods to be noticed. Their addition to some North Central Italian soils (Piccolo and Mbagwu, 1989) increased the aggregate stability of the soils. This was achieved by the adsorption of the humic molecules on the clay particles surface through bridging polyvalent cations to form humus-clay complexes. This adsorption also orientated the hydrophobic components of humic molecules toward the outside of the aggregate thereby, preventing water infiltration. Another study by Mbagwu (1989) and Skinner (1979) conducted with glucose and peptone as substrates on the same soils produced dramatic results. This may have been due to the aeration conditions, variety of microbes decomposing the substrates and the techniques used to determine aggregate stability.

Kinsbursky et al. (1989) demonstrated clearly that municipal sewage sludge, as an abundant source of organic matter, enhanced the stability of soil aggregates of all samples used. They explained this as a situation where fungi-associated polysaccharides bind aggregates by adherence of soil particles to mucilage-covered hyphae, followed by bacterial degradation, re-synthesis and re-deposition of binding materials.

Metzger et al. (1987) stated that the stabilization process itself is primarily microbiological in origin. In their study, Metzger et al. (1987) found that addition of bactericides to a soil sludge mixture increased the per cent of water stable aggregates to a greater degree than the fungicide-treated, sludge-amended soils. This suggests that the fungal activity was a more dominant factor in aggregate stabilization in sludge-amended soils.

Changes in aggregate stability to water induced by high rates of addition of sewage sludge have been observed. Such studies have also shown that at high rates, deterioration of soil physical properties can occur (Mbagwu and Bazzoffi, 1988; Olsen et al., 1970). The explanation to this is that higher manure rates means higher amounts of humic substances and at high rates, humic substances have the capacity to form stronger complexes with polyvalent cations than clay minerals in the inter-crystalline domains. By chelation, these cations may be able to displace the less strongly bound clay particles (Piccolo and Mbagwu, 1989).

Soil organic matter could easily be depleted by excessive microbial activities. This could arise as a result of liming, fertilizer application, ploughing and excessive oxidation. Its depletion would mean a reduction of its influence on aggregation. This underscores the need to constantly replenish it in the soil.

INFLUENCE OF WEATHER CYCLES ON THE STABILITY OF SOIL AGGREGATES

Mr. Vice Chancellor sir, in 1987, I, in collaboration with one Italian soil Physicist, embarked on several studies to explain the environmental consequences of changes in weather cycles on soil aggregate stability. Natural weather conditions have long been recognized to directly influence the formation and destruction of soil aggregates. Seasonal variations through the actions of freezing and thawing and of wetting and drying are such weather conditions that have been reported to affect soil structure (Baver, 1978).

Several workers have documented studies concerning the effect of freezing and thawing (Baver, 1978; Molope, 1988; Mbagwu and Bazzoffi, 1989). Baver (1978) reported that freezing and thawing causes a granulating action on clods, whereas others showed that freezing and thawing decreases the water stability of soils (Mbagwu and Bazzoffi, 1989).

However, a lot of studies on freezing and thawing concentrated on temperate soils where it manifests most, whereas wetting and drying are more of a tropical phenomenon. But according to Baver (1978), the end effect of wetting and drying cycles is similar to that of freezing and thawing cycles in that a breakdown of clods usually occurs. The aggregates may be temporary in nature and not too stable unless sufficient organic matter is present to stabilize them in each case.

Many workers have reported many findings concerning the effects of wetting and drying cycles on aggregation in the tropics (Utomo and Dexter, 1982; Molope, 1988; Mbagwu and Bazzoffi, 1988; Baver, 1978; Richardson, 1976). There are however, some disagreements on the beneficial effects of wetting and drying on the water stability of soil aggregates. Some workers reported that soils subjected to wet-sieving after wetting and drying cycles were more stable whereas our studies found that alternate wetting and drying cycles produced less stable aggregates (Mbagwu and Bazzoffi, 1989). Utomo and Dexter (1982) found that wetting and drying cycles can cause higher water stable aggregates and reduce them within the same soil type. They concluded that in non-aggregated soils, wetting and drying creates planes of weakness which provide the initial faces of aggregates. The existence of these planes of weakness allows the soil to break up into smaller aggregates upon the impact of mechanical stresses by the wetting-up and further agitation by the wet-sieving procedure. In 1972, Baver (1972) proposed the mechanism involved in the desegregation process. According to him drying or dehydration of soil colloids causes shrinkage of the soil mass and cementation of clay particles. Since the drying process is not usually uniform, unequal strains arise throughout the soil mass causing cracks and clods to form. Then, when the mass is wetted, unequal swelling takes place and entrapped air will tend to explode the clod enclosing the air-space. He concluded that repetition of the alternate wetting and drying process causes a disintegration of lumps and clods but at the same time, aggregation of smaller particles may be promoted, a conclusion earlier made by others.

Some workers studied the restoration of structurally degraded soils through the forces of wetting and drying cycles, using buried cores of compacted soils. They concluded that in all the four (4) cores, and under each of the three types of covers (wood land, grass covered and clean-cultivated strip), moisture changes produced a platy structure with shear cracks-usually running horizontally. As the roots of grasses and forest vegetation entered the cores, they nearly always followed these horizontal cracks and often “farmed out” in the plane of the crack. Their work therefore, suggests that favourable structure may return to a compacted soil by the formation of shear cracks, which open the way for root growth. In turn, some of these roots die and are converted by soil organisms which in effect stabilize the unstable plates and blocks produced by wetting and drying forces.

The study of Richardson (1976), while supporting this finding, also showed that if the soil is adequately remixed to achieve reasonable homogeneity, the structural stability of a severely damaged, very fine, sandy loam soil can be restored to a level similar to that of the original soil by the action of alternate wetting and drying and freezing and thawing. He, however, warned that though a normal winter may be sufficient to achieve such a structural regeneration, the possibility of the soil having an appreciably reduced stability in the following spring is more likely.

The contradictory conclusions that are being drawn by researchers in this area have been addressed. According to Molope (1988) early work often did not distinguish between stability changes due to biological activity and those due to physical processes (thixotrophy). Direct physical disruption of aggregates occurs during cultivation or on slaking associated with rapid wetting and air-drying aggregates. Some researchers suggested that physical disruption of aggregates exposes organic matter not previously accessible to microbial attack and results indirectly in decreasing the stability of soil aggregates.

Investigations by Tisdall et al. (1978) and Utomo and Dexter (1982) suggested that in non-sterile soils, microbial activity would compensate for the bonds destroyed by stresses resulting from wetting and drying whereas there is a significant decrease in the stability of soil aggregates under sterile conditions. This has led to the conclusion that the decrease in stability is as a result of wetting and drying cycles which are associated with a decrease in organic matter in soils.

The summary of all these findings is that disruption of aggregates by wetting and drying cycles causes a greater decrease in stability in the absence than in the presence of microbial activity. It would appear, therefore, that when micro-organisms are active in the non-sterile soils, they can produce new bonds from decomposable organic materials in the soil which compensate partially for those broken physically. This is in line with the research conclusion of Molope (1988).

Some other researchers had a more detailed look at the effect of both the individual cycles and their interactions on aggregate stability. Although they showed how the cycles of wetting and drying and simulated cultivation led to a significant decrease in the stability of soil aggregates, their study clearly demonstrated that the longer a soil was kept moist, the less was the physical disruption decreased stability. This is because dryness severely restricted microbial activity in the soil. These findings suggest that dryness has the same effect as sterilization when aggregates are physically disrupted. Thus, the longer a soil is kept moist, after each disruption, the more bonds are produced which in turn compensate for the bonds broken physically.

Two major forces are involved in the driving force for the entry of water, which are determined by the affinity of the internal surfaces for water. The second is the cohesive forces, that hold the particles or aggregates together. As water moves into the system and the affinity of the soil surfaces loose their cohesion and the cementing bonds are destroyed. Prior to the entry of water, there is both free and adsorbed water in the pores.

Water releases the adsorbed air in the pores. If there are no escape pores present, pressures will build up within the aggregates due to the compression of the air, resulting in slaking. If the rate of bond destruction is equal to or greater than the rate of water penetration, there is an orderly, progressive slaking of the aggregates. If the rate is less than that of water entry and there is no build up of air pressure because of the presence of large pores, there is no breakdown of the aggregates. If air is entrapped, however, there is an explosive effect and the aggregates shatter (Mbagwu and Piccolo, 2001).

In effect therefore, there is no slaking of aggregates if carbon dioxide is substituted for air in the system because carbon dioxide is soluble in water and does not develop a gaseous pressure. Also, when wetted in vacuum, there is differential slaking among the materials.

The importance of wetting and drying cycles to agricultural soils could best be seen from the view point of Mbagwu and Bazzoff (1988) that prolonged exposure of wetting and drying cycles will cause dis-aggregation of the soils, which could be beneficial in soils with large (non-aggregated) clods or detrimental in a weakly aggregated soil. As we have theorized and further proved, the deleterious effects of wetting and drying cycles in soils could be cushioned off by the addition of organic matter (in particular, humic acids) (Piccolo et al., 1997).

INFLUENCE OF SURFACE ACTIVE AGENTS (SURFACTANTS) ON THE STABILITY OF SOIL AGGREGATES

The use of surfactants has in recent times attracted greater attention. What are surfactants? These are asymmetric structured substances which consist of a water repellent (Hydrophobic) and water attracting (Hydrophilic) parts in their molecules. The hydrophobic part is generally a long chain of aliphatic carbon, whereas the hydrophilic end varies according to its electrical charge, and it could be classified as either, neutral, negative, positive or amphoteric. Surfactants are therefore, classified as, anionic, nonionic, cationic or amphoteric, depending on their molecular structure. The nature, classes, synthesis and applications of surfactants are discussed in detail by Block and Stache (1982).

Surfactants are water-soluble compounds which are used most extensively in compounding a variety of insecticidal, fungicidal, and herbicidal formulations. Most recent uses include the addition of surfactants to improve the physical properties and wettability of dietary supplements for farm animals.

Several “brand name” wetting agents are available. The factor which they have in common is that their addition to water results in a solution which has a lower surface tension than the original water. When the solution is placed in contact with a solid, the liquid-solid contact angle may be decreased (Pelishek et al., 1962).

The effects of surfactants on aggregate stability of soils (Mustapha and Letey, 1969; Piccolo and Mbagwu, 1989; Mbagwu et al., 1993), on soil moisture evaporation (Law, 1964) and on infiltration into soils (Pelishek et al., 1962) have been studied and reported.

In terms of their effects on the soil environment, the most studied surfactants are the nonionics. However, reactions with cationics and anionics with montmorillonitic soils have been reported by Law et al. (1966). Pelishek et al. (1962) concluded that nonionic surfactants can increase infiltration into hydrophobic soils but have either no effect or adverse effect on soils which are not particularly hydrophilic.

Concerning the effectiveness of surfactants in promoting aggregate stability in soils, a 1% rate (i.e. 20 mg/ha) of nonionic surfactant was observed to increase water-stable aggregates, whereas lower rates had insignificant effects. With anionics, a reduction in the stability of a strongly aggregated soil was reported (Law et al., 1966). Mustapha and Letey (1969) also showed that the application of nonionic surfactant to a hydrophobic soil decreased micro-aggregate stability whereas with a hydrophilic soil, the initial effect was a decrease in stability but its residual effect tended to promote stability.

In an investigation on both the separate effects and interactions of surfactants and humic acids (Piccolo and Mbagwu, 1989), we demonstrated conclusively that while the application of anionic surfactants alone decreased water-stability of soil aggregates, nonionic surfactants increased the stability of soil aggregates, and the interaction of nonionic surfactants and humic acids was positively synergistic in stabilizing soil aggregates.

The action of the nonionic surfactant was as a result of the formation of hydrogen bonds between the polar end of the surfactant and the hydroxyls and oxygen of clay and other minerals, leaving a hydrophobic coating around the soil particles that increased surface tension and thus, water-stability. On the other hand, anionic surfactants which are negatively charged, cannot form strong bonds with polyvalent cations adsorbed on clay but adsorb on clay particles of non-acidic soils only through weak Van der Waals forces and hydrophobic bonds between their hydrophobic parts and apolar soil constituents. The soil coating has a hydrophilic valence in this case that reduces surface tension and increases water infiltration (Piccolo and Mbagwu, 1989).

A similar observation was made by Law and Kunze (1966) by treating two montomorrillonitic soils with eight different surfactants. Also Mbagwu et al. (1993) treated an Entisol and an Ultisol from Nigeria with three anionic and two nonionic surfactants. The anionic surfactants were not strongly adsorbed and tended to remain in the aqueous phase and more in the soil profile with the normal soil migration. The nonionic surfactants, on the other hand, produced beneficial effects from the standpoint of agricultural soils. The effect of anionic surfactants was attributed to its ability to be adsorbed and held by polar bonding forces to clay and other oxygen-rich mineral surfaces.

Law et al. (1964) also reported that cationic surfactants produced the most drastic effects on soil physical and structural properties. They had their greatest effect on soil physical properties by their influence on the water holding and hydraulic characteristics of the treated soils. This might be beneficial or detrimental depending on the view point of the soil scientist. In engineering and foundation problems, cationic materials have been effective soil stabilizing agents by reducing swelling and increasing compressive strength. In agricultural soils however, their detrimental effect on soil-water relations would probably overshadow their beneficial effects on structural properties.

The development and growth of the chemical branch of agribusiness has taken place in Nigeria with little apparent concern for the potential effects that certain of the chemical ingredients might have on the physical and chemical properties of the soils on which they are deposited. We need to know the extent of damage done to the physical and chemical properties of such soils by the addition of these surface active agents to them.

INFLUENCE OF ANTECEDENT MOISTURE CONTENT ON THE STABILITY OF SOIL AGGREGATES.

There is very little directly applicable literature on the influence of antecedent moisture content on the stability of soil aggregates. Cermuda et al. (1953) argued that under natural field conditions, soil aggregates are subjected to degrees of air-trapping and slaking, depending on such factors as initial moisture contents and rates of water application by rainfall or irrigation. Harris et al. (1966) stated that aggregate moisture content at the time of wetting influences the development of initial stress through its effect on the amount of air available for trapping and on the rate of water entry. The later is controlled by the degree of dehydration of the aggregate constituents and by the distribution of moisture-free micro-pores existing in the aggregate.

Dried water saturated aggregates of Peurto Rican soils to obtain moisture contents ranging from an air-dry to a water-saturated condition was attempted. Aggregate stability to raindrop impact was enhanced with increasing moisture content up to a specific moisture content of soils that varied from PF 2- 4.2. It was believed that the higher destructive effects of water on the drier soil was due to the entrapment of large quantities of air inside free micro-capillaries which increased the force with which water was pulled into the aggregates. Aggregates saturated completely were not as stable as those wetted to low moderate tensions (Cermuda et al., 1953).

There is enough evidence to suggest that the influence of antecedent moisture content on aggregate stability is an artifact of the rate of wetting and drying. Panabokke and Quirk (1957) showed that aggregates that were wetted slowly retained maximum stability even when they were wetted to complete water saturation. Similar findings have been reported by other workers.

A marked increase in stability to wet sieving was also observed with aggregates that were collected from a field of relatively high moisture content and allowed to dry gradually. Some workers have discovered that at moisture contents greater than field moisture capacity, aggregate stability decreased and that the stability of oven-dried aggregates was higher than that of aggregates in the air-dry state. The later has been explained as the slaking process in dry cohesive soils. These investigators suggested that the penetration of water into the soil system and its effects on cementing agents are responsible for this action. The particle-to-particle bonding arrangement of oven dry aggregates may have constituted a strong cementing agent, difficult for water penetration as against the soil/water bonding arrangement of dry aggregates. A similar effect of drying on micro-aggregation was attributed to the protection of air entrapped in the micro-pores, thus preventing direct contact of the water with some of the colloidal faces.

Within a certain range of moisture contents, aggregate water stability is related directly to the aggregate moisture condition at the time of testing. The upper level of this range may be a function of the distribution of vacant micro-capillaries existing in the aggregates since appreciable breakdown occurs only when certain micro-pores are free from water. The lower level appears to be associated with excessive drying of the aggregates. According to Harris et al. (1966), this excessive drying may cause irreversible and slowly reversible dehydration of aggregate colloids. This report is in agreement with the findings of other workers, which observed that aggregates wetted to field moisture equivalents (field capacity) and incubated for 24 h were more stable to wet sieving than aggregates treated similarly and wet sieved minutes after moistening.

Highly significant variations in the stability of aggregates < 0.05 and < 0.02 mm in equivalent diameter, due to soils and antecedent moisture levels, was reported in Italy by Mbagwu and Bazzoffi (1988). It was explained that the significant interaction between soils and antecedent moisture levels indicated that soils differed in their response to moisture conditions. This may explain the fact that surface soil aggregates from humid areas showed much more resistance to slaking and water-drop impacts than do subsurface samples. The stability that makes some of these aggregates indestructible by the tests used is associated with comparatively high levels of organic matter. This means that samples with aggregates having high horizontal to vertical axis ratios organic matter were all easily disrupted by slaking. These samples are largely subsoil samples low in organic matter.

The above cited analysis informs the reasoning that resistance to destruction may not be in the same relative order for different soils at different initial moisture conditions. With soils from Italy, (Mbagwu and Bazzoffi, 1988), maximum aggregation occurred at moisture contents near permanent wilting point (approximately – 1.5 MPa tension) while in Peurto Rican soils, many of the aggregates showed considerable stability at air-dryness. Also micro-aggregate stability increased with moisture contents drier than PF 5.5 for other soils (Harris et al., 1966).

Francis and Cruse (1983) and Mbagwu and Bazzoffi (1989) expressed antecedent moisture content in terms of matric potential (Y m). Mbagwu and Bazzoffi (1989) tested the extent to which the antecedent moisture contents of three texturally contrasting soils predisposed them to frost-induced alterations in aggregate stability, using three procedures for evaluation of structural stability. We observed that for the mean-weight diameter (MWD) and the specific dispersion energy of soil aggregates (D), the magnitude of change was dependent on the antecedent matric potential whereas the clay dispersion index (CDI) did not reveal any statistical differences due to antecedent moisture potential. Francis and Cruse (1983) attributed the differences in aggregate stabilities to the methods used in evaluating them. According to them, techniques such as weight-sieving which compares aggregate stability at a matric potential of zero, are likely observing the maximum aggregate stability differences which will occur between soils for common values of matric potential. According to them, since matric potential in the field is seldom zero, the validity of relating aggregate stability differences observed at matric potential of 0 Pa to soil conditions in the field is questionable. They concluded that techniques which compare aggregate stabilities over a range of matric potentials seem more desirable.

THE EUROPEAN UNION RESEARCH GRANT TO INVESTIGATE ORGANIC MATTER POOLS IN TROPICAL (ETHIOPIA AND NIGERIA) ECOSYSTEMS.

Mr. Vice Chancellor Sir, between 1994 and 1998 Professor Alessandro Piccolo (Italy), Dr. Asnakew A. (Ethiopia), Professor Andreux. (France) and Professor J.S.C. Mbagwu (Nigeria), with the passive support of

Professor Henri Insam (Austria), were given a generous research grant to study and relate aggregate stability of cool, tropical highland soils in Ethiopia and hot, lowland soils in Nigeria, with the different fractions of organic matter. The organic matter fractions were extracted from humified organic matter earlier by Eniricerche , Italy. In Florence this was used to study (i) the effects of coal-derived humic substances on water retention and structural stability of Mediterranean soils, (ii) Reduction in soil loss from erosion-susceptible soils amended with humic substances from oxidized coal and (iii) Use of humic substances as soil conditioners to increase aggregate stability. The results of these studies were published in Geoderma, Soil Technology and Soil Use and Management. Thereafter, we concentrated our research efforts on (i) the influence of land use on the characteristics of humic substances in some tropical soils of Nigeria (published in European Journal of Soil Science in 2005), (ii) Changes of humic substances characteristics from forested to cultivated soils in Ethiopia (published in Geoderma in 2006), (iii) Influence of the addition of organic residues on carbohydrate content and structural stability of some highland soils in Ethiopia (published in Soil Use and Management in 2002), and (iv) Carbohydrates and aggregation in lowland soils of Nigeria as influenced by organic inputs (published in Soil Tillage Research in 2004). Earlier we had published a paper from this work on “Carbohydrates distributions in particle size fractions and water-stable aggregates of soils from two contrasting environments" (published in Biogeochemistry in 2001). In all these studies we were able to show that organic matter (in particular humic acids, fulvic acids and humin) were sequestered in the micro- rather than the macro-aggregates. This successful sequestration of organic matter in the micro-aggregates was as a result of hydrophobic bonding or protection of organic matter by physical forces.

We also showed that from the elemental composition and isotopic ($^{13}C/^{12}C$ ratio) analysis of the carbohydrates, using the Interscience EA1108 elemental analyzer, that the isotopic abundance ($\partial^{13}C$) could be related by the following equation:

$$\partial^{13}C \text{ ‰} = (R \text{ sample} / R \text{ standard} - 1) \times 10^3$$

where R = $^{13}C/ ^{12}C$ and the standard is the Pee Dee Belemite (with a value of 0.0112372). The $\partial^{13}C$ ‰ values were rather low (ranging from -25.12 to -31.18) and suggesting that the organic matter was from plants with C3 photosynthetic pathway. We also passed the soluble fulvic acids through non-ionic polymeric resins (XAD-8, SERVA Chemicals) to remove the non-humified organic compounds (mainly saccharides).

For the ^{13}C-NMR spectra of humic extracts from the soils, we analyzed them using the Cross-Polarization-Magic-Angle-Spectrophotometer (CPMAS) technique. The analyses were done with a Bruker AMX400 at

100.625 MHz, using a rotating speed of 5000 ± 50 Hz, a contact time of 1 ms, a recycle time of 1 s and an acquisition time of 13 ms. We made all runs with a variable contact time (VCT) pulse sequence in order to find the optimum contact time (OCT) for each sample and to minimize the error in the evaluation of peak areas. The OCT ranged between 0.8 and 1.0 ms. The line broadening for free decay transformation was fixed at 50 Hz. We identified the following resonance intervals which were associated with these different carbons: alkyl C: 0-50 p.p.m.; C-N in polypeptidic compounds: 50-85 p.p.m.; C-O in carbohydratic compounds: 85-105 p.p.m.; aromatic C: 105-160 p.p.m.; carboxylic-C: 160-200 p.p.m.. We used the areas relative to these resonance intervals (p.p.m.) to evaluate the degree of hydrophobicity (HB/HI) of the humic fractions thus:

$$HB/HI = \{(0\text{-}50) + (105 - 160)\}/\{(50\text{-}105) + (160\text{-}200)\}$$

All integral regions were also corrected for the areas of spinning side bands (SSB) when they appeared in the spectra. Each SSB area was subtracted from that of the region in which it appeared and added to the area of the centre band.

In Nigeria, we studied the structural stability and carbohydrate contents of an Ultisol under different management systems, and showed that the concentrations of acid-soluble, hot water-soluble and cold water-soluble carbohydrates decreased with time of sampling. Also aggregate stability correlated very poorly with all the carbohydrate fractions and OC. The conclusion was that these carbohydrate pools were not very effective in stabilizing the soil aggregates. This study was published in 2001 in Soil & Tillage Research (Adesodun et al., 2001). We also looked at the distribution of carbon, nitrogen and phosphorus in water-stable aggregates of an organic-waste amended tropical Ultisol. In this study we found that the distribution of carbon and nitrogen were very much alike and concentrated mainly in the micro-aggregates (< 0.25 mm), indicating more or less their common origin in the soil, whereas the distribution of phosphorus was random. This study was published in Bioresource Technology in 2005 (Adesodun et al., 2005). Finally we studied the water-dispersible clay in aggregates of forested and cultivated soils in southern Nigeria in relation to organic matter constituents. In this study we related three aggregate stability indices to humic acids, fulvic acids, humin and carbohydrates. In the forested soils these organic matter pools correlated very well with aggregate stability, but were poorly correlated with it in the cultivated soils. Our conclusion is that the role of the organic matter pools is dependent on the cultivation history of the soil and the organic matter fraction we are dealing with (Mbagwu and Piccolo, 1998).

Another area of research we dealt with was the evaluation of biological biomass of organic matter and aggregate stability of some tropical soils. The tropical soils were represented with the Ultisols from the Nsukka plains of south eastern Nigeria. Dr. (Mrs.) Roseta C. Eneje did this study. In her earlier study, she was able to distinguish between biological and physical processes controlling soil aggregate stability. In this present study, she was able to show that the soil biomass is related to aggregate stability in tropical soils. Whether she was using organic wastes or just studying soil microbial pools in forested and tropical Ultisols, Dr. Mrs. Eneje observed that the metabolic quotient was lowest when poultry manure was mixed with rice mill waste. This indicated a possible long-term advantage for the soil C status of this combination treatment.

Dr. (Mrs) Rosetta Eneje is now a Senior Lecturer at the Michael Okpara University of Agriculture, Umudike, Umuahia. I supervised her M.Sc. and Ph.D. degrees
in this University. Another student who is doing her Ph.D. work at the International Institute of Tropical Agriculture (IITA) is Miss Ifenyinwa Monica Okpara. She is trying to identify **"Other Rotation Effects of Cover Crops in Enhancing the Growth and Productivity of Cereals, Represented by Maize".** She has presented her proposal seminar in which she indicated that she will determine Microbial Biomass Carbon, Microbial Biomass Nitrogen, Microbial Biomass Sulphur, Microbial Biomass Phosphorus, etc., and relate each of them to the growth and yield of

maize. The outstanding cover crop she intends to grow is Mucuna beans, which is a good fixer of nitrogen. We hope that very soon she will be telling us that Mucuna produced some Gibberellins and Indole Acetic Acids (IAA) in addition to fixing nitrogen for the utilization of the maize crop.

There is my second Ph.D. student, Professor P.C. Nnabude, the present Dean, Faculty of Biological Sciences, Nnamdi Azikiwe University, Awka. He studied the dynamics of fresh and burnt rice-mill wastes applied on a vertic Ultisol at Abakiliki. The essentials of the study were to see how far these wastes would improve the water-relations of the poorly drained Ultisol. He found out that these rice-mill wastes modified positively the water-relations of this Ultisol by improving its quasi-steady state infiltration rates, moisture it retained at field capacity and permanent wilting point and aggregate stability (Nnabude and Mbagwu, 2002). His Ph.D. defense oral examination took about eight hours to complete. But he has been able to publish scientific papers in impact-rated Journals.

Between 1995 and 1996, I, with Professor Alessandro Piccolo, a Soil Chemist, studied the apparent reductions in organic matter fractions and structural stability following cultivation of tropical forests in Ethiopia and Nigeria. Professor Piccolo traveled to Ethiopia to collect those soil samples and I obtained the Nigerian soil samples from Abakiliki, Nsukka and Umudike. These samples were sent to Portici, Napoli, Italy, for the determination of aggregate stability by three methods, viz, mean-weight diameter of water-stable aggregates, percent water-stable aggregates < 0.25 mm and the clay dispersion ratio (CRD) index, calculated as (clay in H_2O/clay in calgon) x 100. We determined the total carbohydrates, humic acids, fulvic acids and humin and related each of these fractions to aggregate stability. From our results we concluded as follows:

1. Organic matter and its fractions in the forested soils of Ethiopia and Nigeria were reduced after cultivation;
2. Structural stability of the soil aggregates, which used to be high in the forested soils, was reduced by cultivation;
3. The magnitude of such reductions was site-specific and related to the initial state of aggregation of these soils; and
4. In the forested soils, humic acids and humin were responsible for the enhancing of the micro-structural soil stability; whereas in the cultivated soil humic and fulvic acids improved stability indices more than other organic matter fractions (Mbagwu and Piccolo, 2004).

In an earlier study we also did a similar investigation (Mbagwu and Piccolo, 1998), on selected Nigerian soils. We observed that the structural stability of the four soils used was reduced following cultivation. The soils were from Atani, Okigwe, Nsukka and Ezillo. The humic acids, fulvic acids, humin and carbohydrates were similarly reduced and explained individually and collectively, between 66 and 98% variability in structural stability of the aggregates.

IN THE BEGINNING

Mr. Vice Chancellor Sir, I attended four primary schools during my elementary school. I started from Apu-na-Ekpu Community School, Amapu-Umuoha, Isi-Ala Ngwa, went to St Andrew's Primary School, Uratta, then to St. Cyprain's Primary School, Port Harcourt and finally finished at St. Michael's Boys' Primary School, Aba. During these years, I was following and serving my elder brother, Dr. Theophilus Chukwudiere Mbagwu (Associate Professor in Geography), who was a missionary teacher, and posted to many schools during the colonial days. He was a smart teacher and I learnt a lot from him. From St. Michael's Boys' Primary School, Aba, I passed the entrance and went to Ibo National High School, Aba, from 1960 to 1964. After this secondary school, I made a Division One, and passed the entrance to Hope Waddell Training Institute, Calabar. Ibo National High School, Aba, was a rustic school while Hope Waddell Training Institute, Calabar, was urbane and advanced. Between 1965 and 1966 when I finished the Higher

School Certificate (HSC) Examination with a pass in three (3) papers plus a Good pass in the General Paper, I knew that I was a candidate for the University. Following some family problems, I could not enter the University along with my mates. When I entered in 1972, my mates were in their final years in this University. As I already envisioned, I passed in 1975 with a Second Class Honours Upper Division and was immediately hired as a Junior Research Fellow in the Department of Soil Science. In 1977 I traveled to Cornell University, Ithaca, New York, U.S.A. to study for the M.Sc in Environmental Quality and Ph.D in Soil Physics and Conservation. In September, 1981, I came back here, joined the staff of Department of Soil Science, and started being promoted until I was pronounced a Professor of Soil Physics and Conservation in 1992. This was announced in 1999 and I was paid only six months of areas of salary. I became a Professor with 65 publications but today I have more than 200 publications all in impact-factor journals. So I can tell you that Soil Science is a very fertile area, where aspiring researchers can come and make it in record time. I came, I saw and I conquered.

TRIBUTES TO THOSE WHOM THEY ARE DUE

To end this Inaugural Lecture I will like to thank those who made it possible for me to rise above my peers, to this enviable rank. First, my father, late Mr. Gaius Anudike Mbagwu,. His belief in God and what He can do is miraculous. He thought me to have no other God apart from the Supreme Being and to always trust in him for any miracles I expect from Him. Second, my mother, late Mrs. Esther Akwaeke Adanma Mbagwu (nee Ukonu), who showed me that investment in human beings is far better than acquiring plots of land, and buildings in cosmopolitan cities. She almost single-handedly saw me through all the facets of my education and was the only one who gave me five naira when I won the prize as the best-graduating student in the Department of Plant/Soil Science in 1975. To crown it all, none of these two people saw the four walls of a School. Thirdly, my elder brother, Associate Professor Theophilus Chukwudiebere Mbagwu, who showed me that studying for excellence does not kill a person. In Primary School he was easily the best in his class, and because he could not enter Okirika Grammar School, Rivers State, he went to Preliminary Teachers' College, Egbu, Owerri, where he started to record firsts in all examinations he took and thus, gave us the example to follow. Today we are four men in the family, three with Ph.D's and one a Civil Engineer. He helped train us and showed us the way forward academically. Fourthly, my wife, Mrs. Felicia Onyejiuwanaka Mbagwu (nee Onwudiwe), who inspite of nothing, agreed to marry me. She has pretended that I have money for sending out papers but not for the family. I was always pleasantly surprised when she would encourage me to try again when the numerous Obituary Notices would arrive from the Editors of

Journals. Thank you my dear, for investing in me. Fifthly, my numerous brothers and sisters, who carried me as a young lad and made sure no misfortune befell me. Your stout protection of me and my complete protection of you in spite of all difficulties, has shown me that brotherly and sisterly love passes all else. Thank you all. Sixtly, is my childhood friend, Isaac. Your ingenuity and uncommon sense of humour enlivened my days. Although you appear to be unsuccessful in marriage now, your reward is in heaven. Seventhly, my five sons, who are always there for me. The first has graduated Second Class Honours Upper Division in Electronics Engineering from this University. The second is a fourth year student in Medicine and the third, fourth and fifth just entered this University this year. I thank you all for believing in me.

I may use this opportunity to thank my numerous students, in particular, my first Ph.D student, Professor Charles Arinzechukwu Igwe, for selecting me to be his co-supervisor. This was at a time I did not apply for permission to supervise any student. He showed that he knew what he was going to do, and did a very good project that won the Vice Chancellor’s Prize. The present Dean, Faculty of Biological Sciences, Nnamdi Azikiwe University, Awka, was my second Ph.D student. He has a knack for thorough investigation of natural systems. The third was my first supervisee at the undergraduate studies, Professor F.K. Salako, a

Soil Physicist at the University of Agriculture, Abeokuta (UNAAB). He has studiously followed in my footsteps and so, has been rewarded by his University. I wish you all the very best. The many other ranks who I supervised, I wish you God's guidance and protection as you toil along.

Lastly, I have shown in this write up that I started publishing in Impact-Factor Journals. But for what purpose is this? I do not think there was any purpose at all for this. So those who are clamouring for Impact-Factor Journals these days do not have any inkling as to what this stands for. For example, a publication in Adult Education or Agricultural Extension may have an Impact on the local community without any serious meaning to somebody outside the local setting. Does this paper deserve to be thrown away because it was not published in an Impact-Factor Journal in America or Europe or India?

Sometime in the mid-eighties to early nineties, a Vice Chancellor in this University, with the active support of the then Federal Minister of Education, introduced an obnoxious criterion for promotion to the rank of Professor called the Pyramid Structure. First, there must be a Vacancy for this position, and second, irrespective of ones area of specialization, there should ideally be not more than a Professor in a Department. So many hard-working staff could not be promoted. I was due to be promoted a Professor in 1988 but for this policy. It took just a Sole Administrator to counter-balance this logic. He asked: What happens to a hard-working young staff in this University? Must he wait for the death of an elder Professor before he aspires to be promoted? Or should he pray everyday for the death of someone above him before he should be regarded as qualified for promotion? His conclusion was that **“The Igbos are Wicked”.**

So my submission is that whatever goodwill the present Vice Chancellor may have will soon pale into insignificance if he did not reverse this Impact-Factor thing. It does not pay anybody anything to cause the stagnation of another person by imposing an obnoxious policy such as this.

Another area of concern in this University is the role of ASUU (Academic Staff Union of Universities). Every academic staff is supposed to be a member of ASUU. Every month a sizable proportion of our salaries are deducted for ASUU. Then there is a need to elect one of them into the University Council for example, and you see the inverted logic of who is a strong ASUU member and who is not. I think that every ASUU member should be free to contest for any vacant position he or she deems qualified to occupy.

Also the irrational posture of attempting to “fight” the Vice Chancellor for no just course is foolhardiness. If the Vice Chancellor decides to set a trap for any of us we shall be doomed. It happened recently in the Department of Public Administration and Local Government (PALG). Even though the legal implications of this decision are in doubt, the lecturers were sacked and nobody, not even any ASUU member, has dared to ask why. The lecturers involved were too compromised that they could not do anything about it. So the special Assistant to the Vice Chancellor has felt very happy and boastful about this "achievement" and we are the worse for it.

Mr. Vice Chancellor Sir, I have a wonderful family. My wife is the leader of this group of Oliver twists. Once in a while they would ask why I do not travel again. They coped more than my wife each time I was away. This lecture is dedicated to all of them, especially to Mr. Ikenna Nnaemeka Obioha Mbagwu, who chose a field of study which I dared not attempt choosing. Also to Obinna Ugochukwu Mbagwu, who has just passed his degree with a Second Class Honours Upper Division. Your Mother is about to complete her Ph.D degree in Adult Education (Community Development), thereby setting the trend you all should follow. I thank you all.

To the wonderful audience here present, may the good Lord be with you all. It is said in the Holy Scriptures that: **The ways of the righteous are governed by God and He shows us the part to eternal Glory. May the**

Good Lord bless you all. THANK YOU FOR LISTENING.

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