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# Introduction to Scientific Discipline Agrophysics – History and Research Objects

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Additional information is available at the end of the chapter

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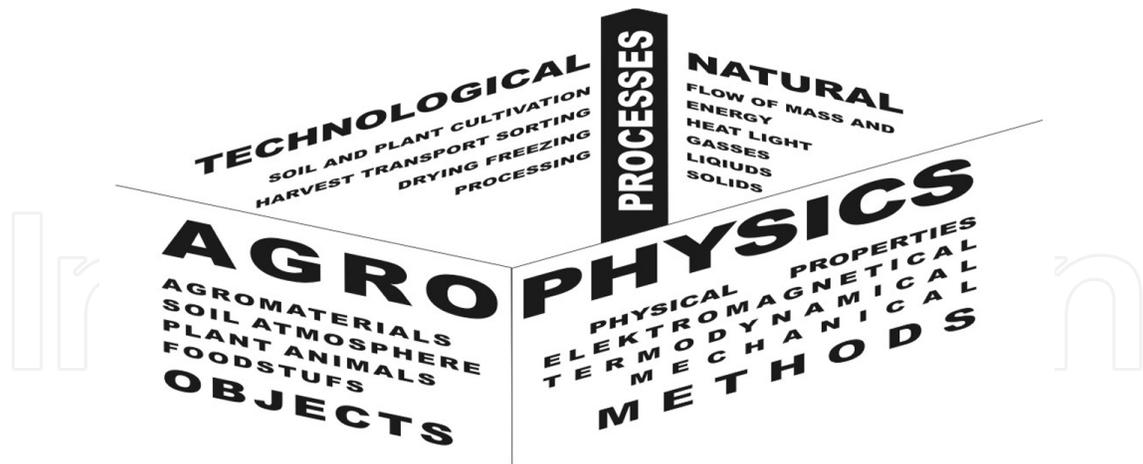
## 1. Introduction

### 1.1. Agrophysics's definition and scope

From the very beginning of its existence the definition of Agrophysics as a science was described a number of times. In general, Agrophysics is a branch of natural and agricultural sciences which applies physics into agriculture. Therefore sometimes it is also called agricultural physics. It explores agricultural materials and processes to describe their physical properties in order to assure best quality of agricultural products or raw material for industry, taking into account the role of environment and other factors. As a field of science, Agrophysics is of interdisciplinary scope and it is closely related to Biophysics. It is however limited strictly to the agricultural environment, i.e., soil, plants and animals and also takes into account the knowledge of Agronomy and Agriculture Engineering.

Agrophysics deals with physical processes in the soil-plant-atmosphere system, taking into account various external factors (climate, impact of the machinery, pollution) and issues related to the growth, harvest, transport, storage and processing of agricultural materials.

Some examples of the wide scope of agrophysical investigation are: developing systems for monitoring and controlling the condition of soil (moisture, salinity etc.) and plant growth (maturity), evaluation of the soil's susceptibility to water and wind erosion, monitoring and diagnosis of soil biological activity, determination of pollution in agricultural products (fruits, vegetables etc.), the assessment of the technological value of grain, evaluation of quality of fruits and vegetables during their storage and changes of their nutrition value during storage.



**Figure 1.** Graphical description of the definition of Agrophysics

The following definition of Agrophysics was recently included in the “Encyclopedia of Agrophysics”:

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“Agrophysics is a science that studies physical processes and properties affecting plant production. The fundamentals (nutrients) and energy (light, heat) transport in the soil– plant–atmosphere and soil–plant–machine–agricultural products–foods continuums and way of their regulation to reach biomass of high quantity and quality with the sustainability to the environment. The knowledge of physical phenomena in agricultural environment allows increasing efficiency of use of water and chemicals in agriculture and decreasing biomass losses during harvest, transport, storage, and processing.”

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Agrophysics therefore aims at ecological use of agricultural ecosystem to assure best quality of agriculture products and the preservation of agricultural landscapes.

## 2. History

In the end of XIX century scientists recognized the need of application of physics to agriculture. The pioneer in this field of research was probably Franklin Hiram King. He was born in 1848 in Whitewater Wisconsin USA. He graduated from Cornell University and served as professor of natural sciences at River Falls State Normal School and after that as professor of agricultural physics at the University of Wisconsin. In 1888 the University of Wisconsin called him to the Chair of Agricultural Physics, the first of its kind in America. F.H. King was interested in a wide range of scientific problems but he made his major contributions to the applications of

physics to agriculture. Most attention was given to soil physics, e.g., he studied water-holding capacities, moisture requirements of plants, aeration, movement of water in soils, movement of groundwater, and the drafts of plows. During his last years in Madison he also began studies of soil fertility. He has been called the “father” of soil physics in the USA.

King published some books, the titles of which prove his scientific interest:

- Elementary lessons in physics of agriculture. F.H. King, 1894. Madison, WI.
- The soil: Its nature, relations and fundamental principles of management. Macmillan, 1895. New York.
- Irrigation and drainage. Macmillan, 1898. New York.
- Physics of agriculture. F.H. King, 1901. Madison, WI.
- Ventilation for dwellings, rural schools and stables. F.H. King, 1908. Madison, WI
- Farmers of forty centuries. F.H. King, 1911. Madison, WI.
- Soil management. Orange-Judd, 1914. New York.

F.H. King’s observations and investigations could be nowadays regarded as a contribution to the so called sustainable agriculture. He died in 1911 in Madison, Wisconsin and his last two books were completed and published after his death.

Beginnings of application of physics in agriculture in Europe were in Soviet Russia. Agrophysical research was commenced in Russia in the middle of XX century. Russian physicist Abram Fieodorovich Ioffe (1880–1960) is regarded as the initiator of this branch of science. He studied measuring methods and used them in agriculture, biology and agrochemistry. He studied electromagnetism, radiology, crystals, high-impact physics, thermoelectricity and photoelectricity. He established research laboratories for radioactivity, superconductivity, and nuclear physics. In 1932 Ioffe organized the Institute of Physics and Agriculture in Leningrad (Sankt Petersburg at present) and became its first director. A.F. Ioffe published two fundamental works entitled: *Physics and Agriculture* (1955), and *Physics for Agriculture* (1959). His successors included: A.F. Chudnovsky (1910–1985), F.E. Koliasev (1898–1958); P.V. Vershinin (1909–1978); I.B. Revut (1909–1978), S.V. Nerpin (1915–1993), E.I. Ermakov (1929–2006), N.F. Bondarenko’s (1928–2003); I.S. Lisker; A.M. Globus, V.P. Yakushev and others. The research topics undertaken by the above mentioned scientists were: mathematical modeling of agricultural production, simulation of agrophysical systems and processes; interaction of biological objects with different physical fields (light, gravity, magnetic, electromagnetic, acoustic, electrostatic), information technologies of production management in arable farming and plant growing, agrophysical instrumentation, elaboration of vegetative systems in controlled climate, a new type of coordinate precision agriculture as the first step to the creation of the “electronic farmer”.

The second scientific Institute whose main field of research is Agrophysics was established in Lublin, Poland. Created in 1968 by prof. Bohdan Dobrzański, the Institute of Agrophysics of the Polish Academy of Sciences was soon recognized as a leading research centre not only in

Eastern and Central Europe, but also in the global research. Numerous professors and younger researchers from the Institute frequently visited leading universities from Western Europe, Japan and the USA, bringing home the knowledge of recent trends and novel methods in the research field. In turn, the high quality of IA staff attracted a number of doctoral students and young researchers from Poland and abroad. This attractiveness, especially to young researchers made the Institute become also a leading educational centre at an advanced level in numerous research areas connected with environment, agriculture and food sector. The results of the research activities undertaken in the Institute were introduced into industry and gave basis for new products and technologies. The outstanding scientists of that period were: I. Dechnik (1929 - 2003), R. Walczak (1943 - 2003), M. Malicki (1939 - 2009), J. Stawiński (1942 - 2005), B. Szot (1933 - 2012), J. Gliński, W. Stępniewski, J. Lipiec, K. Konstankiewicz,



**Figure 2.** Coworkers of prof. B. Dobrzański from the Institute of Agrophysics at the Conference in Prague 1985 (from left; in the front row: R. Walczak, B. Szot, G. Skubisz, B. Dobrzański, J. Gliński; in the second row: M. Molenda, A. Pukos, W. Stępniewski, W. Woźniak, A. Kuczyński, K. Konstankiewicz, J. Lipiec)

The main fields of scientific activity of the Institute of Agrophysics PAS were as follows: investigation of physical and physical-chemical processes of mass and energy exchange in the soil – plant – atmosphere system, physical properties of agricultural materials and processes affecting plant production as well as processes related to gathering, transport and storage of agricultural materials.

The main feature of these studies was the elaboration of new theoretical and experimental research methods, developing of physical – mathematical models and their experimental verification, processing of data, taking into account their variability in time and space. Data bases and thematic maps created in this process can be used in practice for agricultural and environmental protection.

At present, there are more than 100 employees of interdisciplinary character. The scientific staff of the institute constitutes an interdisciplinary team of physicists, chemists, agronomists, horticulturists, biologists, engineers, geographers and mathematicians.

Agrophysics initially focused mainly on the study of soil and plant materials. Over time, this research area started to gradually expand, on the one hand including ever more elements of the soil-plant-atmosphere system, on the other hand, more and more focused on the process of food production and its quality - from the stage of agricultural production through the period of storage of agricultural products, their processing until the final product.

Agrophysics began also to be useful in the wider environment, being a part in the study of not only the degradation of soils, but also researching marshy land formation and greenhouse gas emissions. Currently Agrophysics concentrates on a number of agricultural specialties, it is used to interpret interactions, design, control and optimization of processes. It is also widely used in environmental protection, pedology, tillage and plant engineering, agriculture, agri-food technology, and others.

### 3. Agrophysics in other countries

Agrophysics was developed also in other countries, initially in Eastern European countries. In Czechoslovakia (Prague) R. Řezniček together with his coworkers (J. Blahovec, J. Pecen, P. Hnilica) conducted some important investigations at the Chair of Physics of Prague Agricultural University. They concentrated on physical properties of cereal grains and developed some interesting testing methods. In Czech M. Kutilek from Czech Technical University in Prague conducted advanced studies within soil science too. Also in Hungary (Gödöllő and Budapest) researchers carried out studies on physical properties of agricultural materials: soil, seed, grains, vegetables and fruits. In this context the following names should be mentioned: G. Sitkei, I. Husar, G. Várallyay, I. Farkas and others. Also German researchers joined international agrophysical society. The universities in Hohenheim (H-D. Kutzbach, E. Schlihting, K. Stahr), Bonn (K.-H Kromer), Kiel (R. Horn), Berlin (G. Wessolek) and in Potsdam (J. Helebrand) were engaged in application of physics in agriculture. The events called "Agrofizik Tagung" were organized on a regular base in Germany. These symposiums gathered scientists interested in this topic from Germany. Agrophysics was researched also in Spain. Spanish scientists were interested both in soil (J. Moreno, M. Aranda and D. de la Rosa) and fruit properties (M. Ruiz-Altisant, J. Caniavate). Belgium has also undertaken serious research activities to become a strong agrophysical centre. Catholic University in Louvain (J. DeBaerdemaker, B. Nicolai) and University of Ghent (M. De Boodt, D. Gabriëls) were main centers of agrophysical research there. In France agrophysics was developed in INRA Montfavet (S. Auber, P. Varoquaux), while in Italy the University of Torino (A. Ferero) was the centre of agrophysical studies. Same investigation were also conducted in Belarus and a leader there was I.I. Lishtvan. In Austria prof. W.E.H. Blum interested in some agrophysical aspects of soil sciences. From Slovakia it is necessary to mention Jech.

Agrophysics was developed not only in Europe. A fundamental publication on this topic “Physical Properties of Agricultural Products” has been written by N.N. Mohsenin – scientist of Iranian origin who worked in the USA. Prof. A. Tabatabaefar is a continuator of Mohsenin agrophysical research in Iran. There were also other scientists interested in agricultural physics i.e. S. Gunasekaran, O.R. Kunze, J.I. Ross, G. Brusevitz, F. McClure, Y.A. Pachepsky, S.A. Thompson, P.P. Chen and others. Some topics of applied physics in agriculture were undertaken in Japan (R. Hatano) and China (T. Ren).

In Canada at the Guelph University physics in agriculture was practiced by number of researchers (W.K. Bilanski, R.L. Kushwaha). Also at University of Saskatchewan F. Sosulski. Agrophysics was developed even in New Zealand by C.J. Studman.

In Israel some aspects of agrophysics were studied by I. Shmulevich, E. Bresler, K. Peleg.

The above mentioned names and centres do not exhaust the list of places and persons who conduct their investigations in the field of applied physics in agriculture. These are only examples of people who cooperated with scientists from the Institute of Agrophysics PAS proving that agrophysics is a world-wide recognized science discipline.

#### 4. Agrophysical conferences

Conferences on Agrophysics have always been an occasion for long discussion on all aspects of physical, physicochemical and biological processes of mass and energy exchange in soil-plant-atmosphere system and of plant production, as well as characteristics of agricultural products and materials, agrophysical measuring methods, soil degradation and remediation problems.

Since Agrophysics became a widely practiced discipline of science there were already a number of agrophysical conferences organized. They gathered scientists which main research interests focus on physics in agriculture. The conferences were organized as follows:

- Lublin, Poland 1976, B. Szot;
- Gödöllő, Hungary 1980, I. Husár;
- Prague, Czech Republic 1985, R. Řezniček;
- Rostock, Germany 1989, H.-J. Hellebrand;
- Bonn, Germany 1993, K.-H. Kromer;
- Lublin, Poland 1997, J. Gliński;
- Prague, Czech Republic 2001, J. Blahovec;
- Louven, Belgium 2004, J. De Baerdemaeker;
- Lublin, Poland 2005, R. Walczak;
- Lublin, Poland 2011, J. Horabik;

A number of scientific papers that were submitted and presented during the above mentioned conferences were published both in conference materials as well as in special issues of scientific journals.

## 5. Agrophysical journals

Institute of Agrophysics of the Polish Academy of Sciences is also the publisher of an outstanding scientific journal entitled “**International Agrophysics**”. The editorial board states that: “the journal focuses on physical properties and processes affecting biomass production and processing. The main topics are: mass (water, air, plant nutrients) and energy (light, heat) transport in the soil-plant-atmosphere continuum, ways of their regulation in order to reach biomass of high quantity and quality. The description of new methods and devices for measurements of the physical properties of agro- and biomaterials are published. The journal is also open to wider aspects of environmental and agricultural physics”. The present Editor-in-Chief is prof. J. Gliński.

International Agrophysics is indexed by Journal Citation Reports with 1,574 impact factor.

A second journal published by the Institute of Agrophysics is “Acta Agrophysica”. Acta Agrophysica has been published since 1993. At the beginning it contained mainly monographs and dissertations which were published irregularly. From 2012 Acta Agrophysica is a quarterly. It publishes papers presenting the results of fundamental and applied studies from the field of application of physics for the solution of problems relating to the management and protection of the natural environment, sustainable agriculture, and food processing. Papers can be published both in Polish and English. The present Editor-in-Chief is prof. J. Horabik.

The third journal published by the Institute of Agrophysics is “Acta Agrophysica Monographiae” which publishes reviewed papers based on original research results as well as monographs pertaining to the field of agrophysics. The monographs are published in Polish or English. The present Editor-in-Chief is prof. J. Horabik.

The above mentioned journals are available in electronic versions on the internet.

## 6. Dictionaries and books, maps

In order to facilitate international collaboration and allow unification of terminology, a number of bilingual and multilingual dictionary of agrophysical terms (nomenclature) was prepared under editorial supervision of prof. Ryszard Dębicki and prof. Jan Gliński. The following languages were taken into consideration: English, Russian, French, Spanish, German.

“Atlas of the Redox Properties of Arable Soils in Poland” prepared by Ostrowski, J.; Stępniewska, Z.; Stępniewski, W.; Gliński, J. was published 1996. It contains a wide range of data on soils in Poland presented in the form of cartographic maps. The Atlas gives a comprehensive

information on soils in Poland and can be regarded as a research tool for studying spatial characteristics of agriculture. Practical application of the database lays in the power to generate, for the first time in the world, the thematic maps on spatial differentiation of the redox soil properties throughout the country. A set of these maps has been presented in the published atlas.

The last but most fundamental publication on Agrophysics is the “Encyclopedia of Agrophysics” edited by J. Gliński, J. Horabik and J. Lipiec by Springer in 2011. This book provides an up-to-date information on the physical properties and processes affecting the quality of the environment and plant production. Encyclopedia of Agrophysics is a publication complementary to the Encyclopedia of Soil Science, (November 2007) which has been published in the field of Earth sciences series of Springer. The Encyclopedia presents a set of about 250 informative articles and ca 400 glossary terms covering all aspects of Agrophysics. It contains 450 illustrations on more than 1000 pages.

## **7. Data banks (soil probe bank)**

One of the comprehensive accomplishment of the Institute of Agrophysics PAS is the bank of soil samples collected all over Poland. The collection consists of over a thousand profiles (3 levels) and their full characteristics. This is a unique set of samples which can enable scientists to monitor changes of agriculture environment in Poland.

## **8. Agrophysics – European centre of excellence**

The Centre Of Excellence For Applied Physics In Sustainable Agriculture “AGROPHYSICS” was created on February 28-th. 2003, within the scheme of the 5-th. Framework Programme of the European Union. The project was realized for three years and ended on February 28<sup>th</sup>2006. The main goal of the project was to support the research potential of the region and strengthen its integration with the European Research Area.

The main points of the action plan of the CoE were:

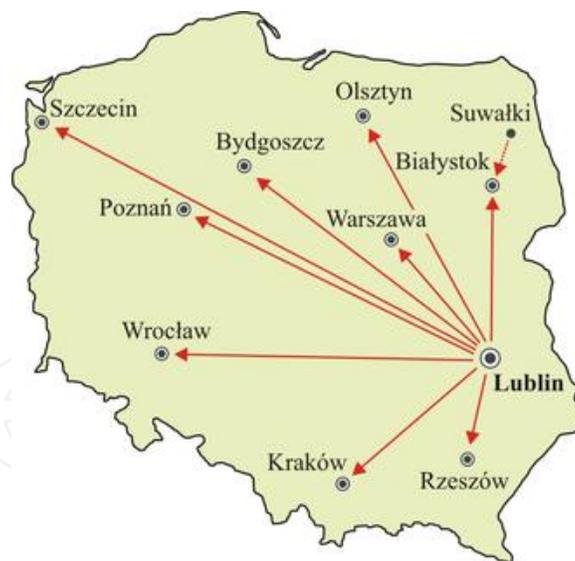
- to develop programmes aimed at significant technological applications, while preserving high standard of fundamental research,
- to concentrate on modern research fields with potential applications in industry,
- to expand the Institute’s activities towards market-oriented research,
- to participate in European projects within European research programmes,
- to intensify activities in attracting funds from the State Committee for Scientific Research (KBN; now – the Ministry of Science and Higher Education) under research grants,
- to start co-operation with Polish industry and SMEs,

- to develop a scientific network with universities,
- to make the IA more attractive for students by combining post-graduate and doctoral studies with a contribution to research projects,
- to establish a Foundation for Development of Agrophysical Research in order to be able to obtain more funds for research.

The prolongation of the existence of the CoE and the consequence of this prolongation was a possibility for dynamic development of the structural base of the Institute. The full renovation of buildings as well as thorough exchange of research equipment was accomplished thanks to European funds.

## 9. Polish Society of Agrophysics

Polish Society of Agrophysics (PSA) was founded in 1996 in Lublin. The initiator and the first president of PSA was prof. Bogusław Szot (1933 - 2012). He has been managing the Society until his death in October 2012. During his presidency ten branches in major scientific centers in Poland were established, where agrophysical investigations are performed (Fig. 3.). The Society is very active and every year it organizes meetings, seminars and symposia. Today PSA comprises over 360 members, among whom over 150 hold the title of full professor.



**Figure 3.** Location of PSA branches in Poland

The main goal of the Society is to agglomerate researchers who conduct their research in the field of agrophysics. The Society has organized nine national and international conferences with over 1400 participants (115 of them from 29 countries outside Poland). Every conference has its own book of abstract, where the most recent results are presented. The most important papers are published in *International Agrophysics* and *Acta Agrophysica* – both journals

edited at the Institute of Agrophysics PAS. Current information on the activities of PSA is distributed through its Information Bulletin.

## 10. Scientific Committee of Agrophysics of Polish Academy of Sciences

The Committee of Agrophysics of Polish Academy of Sciences was established in 1981.

The Scientific Committees of the Polish Academy of Sciences are self-governing, nationwide representation of various disciplines or groups as well as interdisciplinary scientific problems integrating scholars throughout Poland. The scientific committee includes the Members of the Polish Academy of Sciences of the relevant specialty (outstanding scientists), eminent researchers representing universities, institutes of the Polish Academy of Sciences and the scientific institutes and research departments, as well as representatives of other institutions, including economic and social organizations. The scientific committees of the Polish Academy of Sciences are the most representative group of experts in the discipline.

The main task of the Scientific Committee of Agrophysics is to promote research of physical and physicochemical properties of the natural environment with particular emphasis on the system: soil-plant-atmosphere-machine-crops, agricultural-machine-food products. At present the chairman of the Committee is prof. Bohdan Dobrzański Jr.

Actually there are three sections operating within the structure of the Committee:

- Section of Physics Application in Engineering of Agricultural Production and in Food Technology,
- Section for Physical Measurement Techniques for the Agricultural Environment Protection,
- Section of Physical Methods of Evaluation of the Quality of Agricultural Products.

Since the beginning of its existence the Committee's special attention was directed to the integration of the scientific community and its involvement in the process of creatively solving important problems in agricultural research. The Committee in its activities focused also on identifying the main areas of research and science policy in the agrophysics. In previous years the Committee also financed research projects in the field of agrophysics. It has developed extensive cooperation with other committees working in the field of agricultural sciences. It also promoted international cooperation as a partner institution in organization of international conferences.

## 11. Foundation for Development of Agrophysical Sciences (FRNA)

Foundation for Development of Agrophysical Sciences was established for the purpose of supporting and promoting the development of agrophysical research and activity of the Institute of Agrophysics PAS. The implementation of the main goals of the Foundation is

achieved by publishing (Scientific Publishing House of FRNA) in the field of natural sciences and application of physics in agriculture. According to the up-to-date techniques, the Foundation proposed e-files i.e. electronic publications on CD and DVD instead traditionally printed books. The Foundation also sponsors various initiatives and initiates actions toward popularization of agrophysics as science.

## 12. Prototype apparatus and investigation methods

For many years a workshop for prototype apparatus production was being organized at the Institute of Agrophysics PAS in Lublin. A number of pioneer measuring techniques were elaborated and used in innovative apparatus. Both construction and production of this equipment was realized at the Institute. The founder and the first manager of the workshop was M. Grochowicz, PhD.

Under this activity a measuring systems for determination of moisture content and salinity of soil and other porous materials has been elaborated. The measuring techniques are based on the Time-Domain Reflectometry (TDR) which is worldwide patented. In the last years an innovative silo for drying and safe storage of rapeseed was constructed. The silo allows automated post-harvest drying, cooling, and storage of rapeseeds in neutral gas atmosphere to assure best quality of raw material for oil production. It prevents the development of heat processes as well as moulds and fungi growth in stored seeds. Also some prototype measuring apparatus were elaborated in order to evaluate quality parameters of fruit tissue especially apple tissue.

All the above mentioned activities, institutions and persons prove the necessity and usability of Agrophysics as a branch of applied science, which can help to solve current problems in agriculture and which can benefit in progress of this part of economy.

### Author details

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