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# Academic exchange between the University of Vermont and Oberlin College, USA, and the Center for Environmental Studies of Cienfuegos (CEAC), Cuba

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Abstract

Since the triumph of the Cuban Revolution, relations between Cuba and the United States have been very tense, making collaboration between scientists from both nations difficult. Despite this, in 2018, researchers from the American universities of Vermont and Oberlin and the Cienfuegos Environmental Studies Center from Cuba proposed an academic exchange, based on the execution of a research project. The main objective was to evaluate the implications that the transition from intensive to conservation agriculture has had on the landscape of Cuba. The technique used to evaluate soil erosion in these two periods was the nuclear technique, based on the use of radionuclides as environmental tracers. Low-background gamma spectrometry was used to measure radionuclides. In addition, the waters and sediments of the monitored rivers were chemically characterized, about which existed scarce information. Metal concentrations in sediments were determined by X-ray fluorescence. The objectives proposed in the project were achieved and the results corroborate the positive impact of conservation agriculture on water quality and soil protection. The academic exchange carried out is an example that collaboration between scientists from Cuba and United States is possible and necessary. This scientific activity was developed in a friendly and respectful environment, where Americans and Cubans worked together and shared their experiences and knowledge.

***Keywords:*** *academic exchange, soil erosion, water quality, radionuclides*

## Introduction

The academic exchange between the U.S. universities of Vermont and Oberlin with the Center for Environmental Studies of Cienfuegos, Cuba, was preceded by several communications between researchers from both countries who had found related topics in their work, thus arising a mutual interest in collaboration.

The United States (U.S.) scientific leaders, Oberlin College Assistant Professor of Geology, Amanda H. Schmidt PhD, and University of Vermont Professor of Geology, Paul R. Bierman PhD, found in the searches that they had carried out, that there were similarities in their research. Bierman, found in the bibliographic searches of their interest, scientific articles related to the application of nuclear techniques in investigations of soil erosion and sedimentation processes, by CEAC researchers, among them, Dr. Carlos M. Alonso Hernández, Dr. Misael Díaz Asencio (sediment dating using lead-210 (210Pb)) and Rita Y. Sibello Hernández (soil erosion using cesium-137 (137Cs)). Thus the idea of scientific exchange was born. On the Cuban side, it was Dr. Sibello Hernandez, who led the processing of the official protocols to carry out the exchange with the researchers from the United States with the Department of International Relations of the Ministry of Science, Technology and Environment of Cuba (CITMA), and obtained the approval.

It was at the end of January 2018, when the CEAC institutions received Dr. Schmidt and Dr. Bierman from the United States for the first time. CEAC was represented by its then director, Reinaldo A. Acosta Melián PhD, Dr. Alonso Hernández, Dr. C. Sibello Hernández and other researchers and specialists of the institution. The meeting lasted two days and the scientific leaders of both nations presented their experiences in the topic of interest as well as their main results.

The work agenda concluded with the presentation of a research project related to erosion processes in important watersheds in the central, western and eastern regions of Cuba. The project would involve the joint participation of researchers, specialists and students from the three institutions. The funds would be covered by the National Science Foundation (NSF) of the United States; and Cuba's Agency for Nuclear Energy and Advanced Technologies (AENTA) would finance the national projects "*Use of Nuclear and Isotopic Techniques for Greater Efficiency in the Management of Water and Soil in Agriculture, Linked to Climate Change Adaptation and Mitigation Strategies - ISOAGRI*", led by Sibello Hernández, and "*Proyecto Soluciones a Problemas Específicos del Manejo Integrado de Cuencas y Áreas Costeras en Cuba, a través de Técnicas Isotópicas y Nucleares (TIN) -MICATIN*" led by Alonso Hernández, which would function as counterpart projects.

The idea of the project is based on the fact that -as is well known- in order to avoid the negative effects of deforestation and intensive and mechanized agriculture, conservation agricultural practices are often employed. Although these lower impact practices have been implemented around the world, the results have rarely been quantified at the landscape scale. In this sense, Cuba is shown as a unique test laboratory, in which, for 30 years after the revolutionary triumph, large-scale industrial agriculture was developed, characterized by the use of heavy machinery, pesticides and fertilizers, which —hypothetically— should be related to negative environmental impacts of pollution and increased erosion-sedimentation processes, until the 1990s, when the socialist camp disappeared and our country was isolated and agricultural supplies began to be scarce. Since then and up to the present, organic and conservation agriculture has been practiced, which means a substantial decrease in pollution and soil erosion.

This fact led to propose the research hypothesis that the implementation of the project would allow the evaluation of the effects of conservation agriculture in reducing the extent of erosive processes and would allow the comparison of natural changes in the landscape in the long term.

All participants in the first meeting agreed that the implementation of the proposed research project would be beneficial for both countries. For the Cuban researchers it would be an opportunity to train in sampling and to become acquainted with novel analytical techniques used for the quantification of soil erosion and sedimentation by other methods based on the measurement of 10Be and 26Al isotopes. The academic exchange would favor the transfer of the know-how of the technique to the Cubans and would allow comparing the results expected within the framework of the collaborative project with those existing in the country, thus validating the implemented methods. In addition, they would determine the erosion and sedimentation rates in sites of interest, where there is insufficient data on these environmental processes.

For the U.S. researchers, the motivation would be the unique opportunity to apply these methods of erosion-sedimentation studies in different socio-environmental conditions, which would contribute to their strengthening as researchers, in addition to exchanging experiences person to person with researchers from Cuba.

**Development**

A particular group of environmental radionuclides, called radionuclides from radioactive fallout, are used to determine the magnitude of erosional processes and over what period of time they have occurred. These include artificial radionuclides such as cesium-137(137Cs) and geogenic radioisotopes such as lead-210(210Pb) and more recently cosmogenic radionuclides such as beryllium-7 (7Be). These have been used globally to obtain rates and patterns of soil erosion and deposition at various temporal and spatial scales (Zapata & Nguyen, 2009; Mabit, 2008; Zapata, 2002).

Cs137 is an artificial radionuclide, a product of the nuclear fission of uranium-235 (235U), which exists in the environment especially due to the high-powered open-pit nuclear tests that took place mainly during the 1950s and 1960s, which caused measurable quantities of this radionuclide to be emitted into the stratosphere and dispersed almost homogeneously throughout the planet due to atmospheric movements. Then, through atmospheric "fallout" deposition, the radionuclides reached the earth's surface and became strongly bound to fine soil particles, becoming an unparalleled radiotracer of the physical movements of the soil. This, together with the radioactive properties of 137Cs: a relatively long half-life of 30.2 years and its easy detection by gamma spectrometry, thanks to its characteristic emission line of 662keV, make it possible for it to be used to study soil distribution in the landscape (Ritchie & Mchenry, 1990; Walling & Quine, 1991; Walling & Quine, 1993).

On the other hand, Pb-210 is a naturally occurring radionuclide belonging to the radioactive uranium-238 (238U) series. From the 238U in the ground, radium-226 (226Ra) is produced by radioactive decay, which in turn, upon decay, forms radon-222 (222Rn), which is a noble gas. By the disintegration of 222Rn, trapped in the soil, plomosoport (210Pbsoport.) is formed in the same soil. Another part of the 222Rn diffuses through the soil, passes into the atmosphere and in its radioactive decay originates 210Pb. This 210Pb, formed in the atmosphere, reaches the soil by atmospheric precipitation, producing an excess of 210Pb in the soil (210Pbexc.) (Walling & He, 1999).

Due to the atmospheric origin of 137Cs and 210Pb exc. their distribution in the soil profile are similar and they are found in the upper soil layers. However, the soil entry times of these radionuclides are different. The entry of 137Cs into the soil occurred mainly in the 1960s, a time when intensive agriculture was being developed in Cuba. The 210Pb exc. is deposited in the soil continuously. Thanks to this difference, by determining the presence or absence of both radionuclides, it is possible to evaluate the characteristics of soil erosion, given by its speed and depth (Walling & Woodward, 1992).

When 137Cs is present, the soil experiences slow surface erosion during and after 137Cs deposition (1945-present). When 137Cs is absent, the site experiences rapid and deep erosion during or after 137Cs deposition. When 210Pbexc. is detectable, the site is experiencing slow surface erosion. When 210Pbexc. is absent, the site is currently experiencing rapid and deep erosion. By determining the presence or absence of both radionuclides in soil samples, we can evaluate past and present soil erosion characteristics (Walling & Woodward, 1992).

On the other hand, landscape-scale denudation is known to occur by both physical removal of mass (erosion) and the chemical dissolution of minerals in rocks. Sediment produced by bedrock erosion moves downslope to the base level, while rock dissolution moves mass in solution from the landscape to rivers and then to the ocean. Thus, measurement of cosmogenic nuclides in river sediments can be used to infer the spatially averaged sediment generation rate of a drainage basin (Brown *et al*., 1995; Granger *et al*., 1996; Bierman & Steig, 1996), but does not provide information on processes, such as rock dissolution, that occur at depth. Assuming a source rock density, equivalent rates of landscape reduction over time can be calculated.

In a steadily eroding basin, the concentration of nucleidocosmogenics in a sediment sample reflects the rate at which mass was removed from and near the surface as material was exhumed, both through physical weathering and rock dissolution (Lal, 1991). Measurement of multiple nucleidocosmogenic nuclides with different half-lives (radioactive half-lives) in the same sample can provide further information on the exposure history of surface materials, such as soil mixing and residence time (Lal & Chen, 2005), as well as sediment storage within the watershed (Granger&Muzikar, 2001). Among these nucleidocosmogens are aluminum-26 (26Al) and beryllium-10 (10Be). 26Al is produced from atmospheric argon (Ar) due to the spallation of cosmic ray protons (i.e., protons with very high energy). Beryllium-10 (10Be) is also produced in the Earth's atmosphere by spallation, produced by the bombardment of high-energy cosmic radiation on oxygen and nitrogen nuclei.

Because beryllium tends to exist in aqueous solution at pH values lower than 5.5, this atmospheric beryllium. s washed away by rainwater (whose pH is usually lower than 5.5), Once in the ground, the solution becomes alkaline, precipitating beryllium that remains stored in the soil for a long time (half-life of 1.387 million years). It is known that the production ratio of 26Al/ 10Be, at the surface in mid and low latitudes is ~6.75 (Nishiizumi *et al*., 1989; Balco *et al*., 2008). This ratio has been used to study the role of sediment transport, deposition and storage, and erosion. If sediment that has accumulated cosmogenic nuclides is buried in such a way that its production is negligible, this ratio decreases because 26Al disintegrates faster than 10Be.

Similarly, vertical mixing within a soil column has the effect of increasing the near-surface residence time of sediment grains, suppressing the 26Al/10Be ratio in sediment detached from the landscape surface during erosion (Makhubela *et al*., 2019).

All these fundamentals described above constitute the basis for the techniques implemented in the research within the framework of the proposed collaborative project.

In the month of August of that same year, 2018, the Cuban researchers had adequately processed the flying visas and customs permits for the arrival of the North American colleagues, accompanied by the equipment that would be used in the field activities of the project, as well as the permits to access the natural areas that would be monitored in the central region of Cuba.

The group of researchers that carried out the first campaign was made up of 7 Cubans and 6 North Americans, including, in addition to the scientific staff, science and environmental writer Joshua E. Brown of the University of Vermont and the University of California, Berkeley, and on the Cuban side Maikel Hernández Núñez, CEAC communicator. Joshua and Maikel were involved in these activities and were to fulfill their mission of communicating to a wider audience the execution and achievements of the campaign.

The scope of the campaign was to collect water and sediment samples in about 30 sites in the provinces of Villa Clara, Sancti Spiritus and Cienfuegos. The selection criteria for these sites were given by several factors. First, they should have representative watershed slopes of these provinces and should be representative of the intensity of land use, agricultural use and vegetation and, finally, the watersheds to be monitored should be large enough to have streams that accumulate and transport a lot of sediment from erosion within the watershed. The objective was to elucidate the magnitude of erosional processes on the landscape over a considerable time (over 50 years), which included a first period of approximately 30 years (1959-1990) of intensive agriculture, followed by a similar time period (1990-2018), but of conservation agriculture. This crusade initiated an extensive work schedule, contributing to "agricultural research and management techniques for soil and forest conservation", one of the eight areas of cooperation contemplated in the Memorandum of Understanding between the United States Department of Agriculture (USDA) and the Ministry of Agriculture of Cuba, signed on March 21, 2016 (USDA, 2016).

To accomplish the campaign, the personnel was divided into two groups, trying to have an equal number of Cubans and Americans in each group, which would facilitate the exchange between researchers of the two nations. One group was led by Paul Bierman and Alejandro García Moya Msc, the latter a CEAC researcher. In addition to other specialists and students, this group included Joshua, the American journalist. The other group of researchers and students from both countries was led by Amanda Schmidt and Rita Sibello, accompanied by Maikel Hernández, the CEAC communicator.

For this purpose and to characterize the environment, 25 rivers were selected in the central region, with different land uses, from forest to agricultural use, and the sites selected for investigation were divided between the two groups, each of which would cover different sites. At each sampling site, river sediment samples were collected and sieved, taking samples smaller than 63 microns and samples with a particle size of 250 - 850 microns (Figure 1). From each sample, one half went to the CEAC Environmental Assay Laboratory (EAL) and one half to the U.S. university laboratories. The samples were packaged in nylon bags and properly labeled to identify the source site and carefully transported. These samples, both at the LEA and at the foreign laboratories, would be analyzed by X-ray fluorescence (XRF), gamma spectrometry, and the stable isotopes of carbon and nitrogen would be determined.

Figure 1. Science and environmental writer Joshua E. Brown of the University of Vermont takes images as U.S. and CEAC researchers screen sediments. Brown of the University of Vermont takes images as U.S. and CEAC researchers perform sediment sieving. Photo: Maikel Hernández

For the river water samples, different parameters such as temperature, dissolved oxygen and conductivity, which characterize the monitored rivers, were determined in situ and duplicate samples were also taken for isotopic analysis at the LEA and in the laboratories of US universities (Figure 2). Also, the most probable number (MPN) of E. coli bacteria was determined in the water samples from the monitored rivers, incubating them in the field (Figure 3). In addition, the concentrations of some anions present in the water, such as nitrates, chlorides and phosphates, were determined in the field.

Figure 2. The team of Cuban and U.S. researchers filtering river water for subsequent anion and stable isotope determinations in the laboratories of both countries. Photo: Maikel Hernández.

Figure 3 Researchers Amanda H. Schmidt, Oberlin College, Paul R. Bierman of the University of Vermont, Alejandro Garcia Moya and Rita Y. Sibello of CEAC, during bacteriological incubation of samples. Photo: Joshua Brown.

The first monitoring campaign in the central region of the country was successful; the proposed objectives were met and a broad characterization of the monitored watersheds was achieved. Important conclusions were reached that corroborate the benefits of conservation agriculture for the environment. Cuba's transition to today's sustainable agriculture, also involving the reduction in the use of chemical fertilizers per hectare of soil, has resulted in a much lower concentration of nutrients in the waters of the rivers investigated and, therefore, a higher quality of their waters, which is an example for other types of economies. With respect to erosive processes, it has resulted in a decrease in the speed and depth of erosion, contributing to the recovery of soils.

The results obtained by these researchers in the campaign performed in the central region of Cuba were published in the prestigious scientific journal GSA Today (Bierman *et al*., 2020). In this publication, the authors concluded that the composition of water and the presence of total dissolved solids in the rivers of the central region vary with the type of rock, suggesting a close connection between water chemistry and the underlying rock units. For example, the high concentrations of calcium (Ca) and magnesium (Mg) and alkalinity in many samples are consistent with the mapped presence of carbonate rocks in the drainage basins.

At other sites, where the bedrock consists of post-Eocene marine sediments, higher values of rubidium (Rb), strontium (Sr), barium (Ba) and uranium (U) were found than in other rivers (Figure 4).

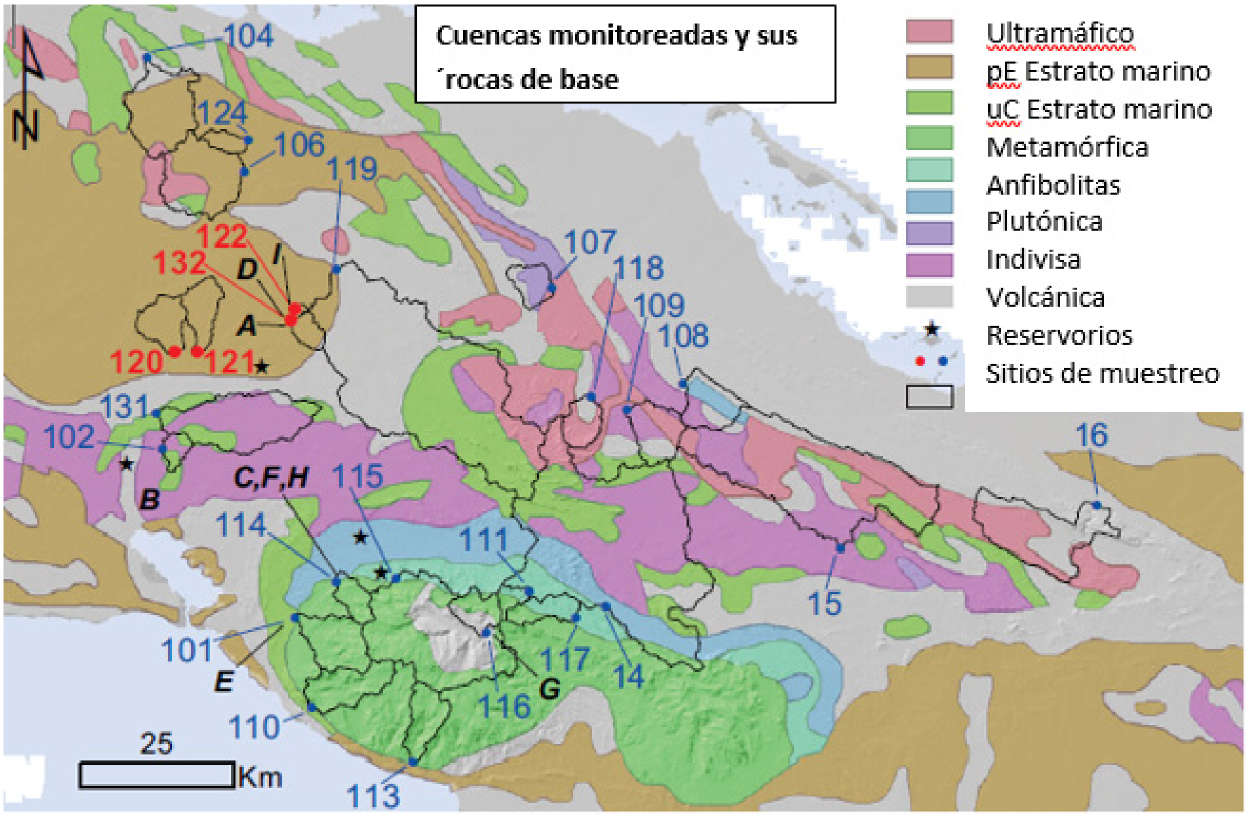


Figure 4. Geological map of the monitored basins (French & Schenk, 2004). Source: Bierman *et al*., 2020.

The group of scientists, thanks to chemical analyses carried out in the laboratories of both nations, determined that arsenic (As), barium (Ba), chromium (Cr), manganese (Mn), nickel (Ni), strontium (Sr) and uranium (U) were present in some of the river water samples analyzed, but in all cases these values were below the maximum permissible concentrations for drinking water.

These researchers also stated that the values obtained for Conductivity and Total Dissolved Solids (TDS) in the river waters were high (130-1380 µS/cm) and from 117 to more than 780 mg/L, respectively. They consider that high TDS values are not dangerous, but could limit some water uses and that these high TDS values could cause clogging of industrial and domestic pipes. The pH values were neutral to slightly alkaline with high bicarbonate values (65-400 mg/L) (Bierman *et al*., 2020).

Another parameter measured in river waters was dissolved oxygen (DO), measured in situ, with values ranging from 59% to 145% and an average value of 97% (Bierman *et al*., 2020). DO is essential for the decomposition of organic matter by bacteria, which helps maintain the balance of ecosystems.

The bacteriological analysis of the monitored river waters of the central region showed the presence of E. coli in all these rivers and is related to the existence of animals in the nearby surroundings, the development of livestock and the use of farm equipment for transportation.

Resulting from this investigation, high rates of weathering and denudation of the landscape were calculated and thus inferred the presence of flow paths through the fresh rock. In general, the field determinations of anions correlated well with the values subsequently determined in the laboratory.

The tests performed at both the CEAC and the U.S. laboratories allowed comparisons between them, which served as a quality control of the analytical results.

In their article (Bierman et al., 2020), these researchers conclude that the river waters of central Cuba are evidence that agriculture does not need to contaminate rivers, reservoirs and coastal areas with nutrients. Nitrogen and phosphorus are present in Cuban rivers, but at lower concentrations than in the waters of the United States, where agriculture is intensive and much fertilizer is used. Fertilizer use in Cuba peaked in 1978 and then declined, while fertilizer use in the U.S. has remained high since 1961. Sustainable agriculture implemented in Cuba after the Soviet assistance era has resulted in less fertilizer use and higher river water quality, said researchers from both nations.

"These results are a comprehensive snapshot of the chemistry of water moving through rivers in central Cuba," said Dr. Bierman.

> By reducing sediment and manure loads, economic benefits can be achieved, because rivers discharge into the coastal zone, where suspended sediment and bacteria from agricultural activity negatively impact water quality and transparency in coral reefs and beaches, frequented by tourists, a source of income for Cuba," say the researchers (Bierman *et al*, 2020).

Another achievement of the Vermont-Oberlin- CEAC academic exchange was to be able to interpret, by means of nuclear and isotopic techniques, the erosive and denudation processes that have taken place in the hydrographic basins of the central region that were monitored during the first campaign.

These results were published in the scientific journal Geochronology

> Terminology referring to watershed mass loss has been ambiguously applied in the past and can be confusing. Here, reference is made to the rate of landscape mass loss calculated from 26Al and 10Be concentrations as erosion rates; these rates include all processes (physical and chemical) that remove mass within approximately 2 m, from the Earth's surface (Campbell *et al*., 2022).

Landscape mass loss rates inferred from stream water chemistry measurements, combined with estimates of annual runoff volumes, refers to rock dissolution rates. The term denudation is used to refer to the total mass loss from the watersheds sampled. All these rates are expressed in terms of mass per area per time (Mg km2 yr-1), which can be converted to depth over time assuming rock density (Campbell *et al.*, 2022).

These researchers (Campbell *et al*., 2022), detail in their article that using measurements of 26Al and 10Be, contained in the sands of the 25 rivers monitored, together with estimates of the flow of the dissolved load in the river, it was possible to characterize the processes and the rate of change of the landscape in the central region of Cuba. These authors state in this work that long-term erosion rates inferred from 10Be concentrations in the quartz extracted from the sand of the rivers of central Cuba range from 3.4 to 189 Mgkm2yr-1 (mean 59, median 45). Dissolved loads, calculated from solute concentrations in the modeled stream and runoff, range from 10 to 176 Mgkm2yr-1 (mean 92, median 97), which, in 18 of 23 watersheds, exceeded erosion rates derived from 10Be cosmogenic. This disparity —according to these authors— indicates that, in this environment, landscape-scale mass loss is not fully represented by nucleido-cosmogenic measurements.

The 26Al / 10Be ratios were found to be lower than expected for steady-state exposure or erosion in 16 of 24 samples. Reduced26Al /10Be ratios were obtained in many of the basins having the greatest disparity between dissolved loads (high) and erosion rates inferred from concentrations of cosmogenic nuclides (low).

Reduced 26Al/10Be ratios are consistent with the presence of a deep, mixed regolith layer that provides extended storage times on slopes and/or prolonged burial and storage during fluvial transport. Chemical analyses of river water indicate that many basins with lower 26Al/10Be ratios provide extended storage times on slopes and/or prolonged burial and storage during fluvial and high 10Be concentrations are underlain, at least in part, by rapidly dissolving evaporite rocks (Campbell *et al*., 2022).

These authors state in their scientific paper that the data obtained show that, when assessing mass loss in the humid tropical landscape, it is particularly important to take into account the contribution of rock dissolution at depth. In such hot and humid climates, mineral dissolution can occur many meters below the surface, beyond the penetration depth of most cosmic rays and, therefore, of the production of most nuclides and cosmogenic nuclides.

The researchers (Campbell et al., 2022) concluded that their data suggest the importance of estimating solute fluxes and measuring nuclide-cosmogenic pairs to better understand processes and rates of mass transfer at the basin scale.

**Conclusions**

Cuba's transition to today's sustainable agriculture (and reducing fertilizer use per hectare of cropland) has resulted in much lower nutrient concentrations in the rivers of central Cuba than in the water of the Mississippi River in the United States and is a model for other types of economies, the research team said.

The group of scientists also believes that the implementation of other management strategies to reduce manure and sediment loads (such as keeping livestock away from rivers) could in the future bring rapid improvement in river water quality and consequent economic benefits to the country.

The results of these investigations contributed to the Cuban State Plan to confront climate change (Tarea Vida), specifically with regard to soil and water protection, providing a diagnosis of soil erosion in the sites studied, as well as water quality, related to the deposition of sediments originated in erosive processes and the presence of pollutants associated with these sediments, closely linked to anthropic agricultural and livestock activity.

On the other hand, public communication played an important role in the research and the participants in the Cuba-US academic exchange consider that Cuba can be a catalyst to increase public awareness of the importance of soil conservation.

The performance of the academic exchange between Cuban and American scientists demonstrated that differences in ideologies and economic systems do not matter when there is maximum respect, tolerance and acceptance of inequalities. In the Vermont - Oberlin - CEAC exchange, a fraternal atmosphere of respect and solidarity prevailed at all times, given by the common objective of having a good performance in the execution of the project and the results obtained speak for themselves.

The following year, the delegation of experts from U.S. and Cuban institutions met again in the Caribbean nation to carry out the second sampling campaign in the province of Pinar del Río. This will be material for another paper.

**Profiles**

The University of Vermont is a state university in Burlington in northwestern Vermont and is recognized in the fields of biology, environmental, agricultural and life sciences. Oberlin College, located in Oberlin, Ohio is a private college, a member of the Association of Great Lakes Colleges and Universities and the Five Colleges of Ohio. Its most popular majors have been English, Biology, History, Politics and Environmental Studies.

The Cienfuegos Center for Environmental Studies is a research center attached to the Ministry of Science, Technology and Environment (CITMA), dedicated to the study and solution of environmental processes, recognized by the International Atomic Energy Agency (IAEA) as a Regional Reference Center for the application of nuclear techniques to the solution of specific problems of integrated coastal management, since 2007. It is currently accredited as a "Collaborating Center of the International Atomic Energy Agency (IAEA) for the Application of Nuclear and Isotopic Techniques in the Study of Marine-Coastal Ecosystems in the Latin American and Caribbean Region".

**Articles published on the results of the U.S.-CEAC exchange, Cuba**

In Cuba, Cleaner Rivers Follow Greener Farming. doi.org/10.1130/GSATG419A.1

¡Cuba! River Water Chemistry Reveals Rapid Chemical Weathering, the Echo of Uplift, and the Promise of More Sustainable Agriculture (2020, March-April) . *GSA Today, 30*(3-4).

Cosmogenic nuclide and solute flux data from central Cuba emphasize the importance of both physical and chemical denudation in highly weathered landscapes. 2021. https:doi.org/10.5194/gchrom

**Results presented at scientific events**

- MARCUBA, Habana, 2018: Water Quality of central Cuban rivers; implications for the flux of material from land to sea.
- Ecoagua Workshop. Hanabanilla. March 2020. Paper: Evaluación del Impacto de la Meteorización Química y de la Agricultura Sostenible en la Calidad de las Aguas de los ríos de la Región Central de Cuba.
- XVI Forum de Ciencia y Técnica del CEAC. June, 2020. Paper: Evaluación del Impacto de la Meteorización Química y de la Agricultura Sostenible en la Calidad de las Aguas de los ríos de la Región Central de Cuba.

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