Proposal for Research Cluster

Joint Research and Education Program "Palestinian-German Science Bridge PGSB"
Forschungszentrum Jülich GmbH & Palestine Academy for Science and Technology

Topic of research cluster

Closing nutrient cycles for agricultural sustainability: wastewater to algae to soil to plant

Proposed participants

Cluster representative at Forschungszentrum Jülich (if applicable)

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Institute	Job title
IBG-2	**Other**

University affiliation
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Cluster representative at Palestinian university (if applicable)

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Home university and faculty/department	Job title
Palestine Polytechnic University	**Researcher**

Proposed cluster participants in Jülich/German universities:

Dr. Steven D. (Dean) Calahan, visiting scientist (Jülich) Dr. Silvia Schrey, staff scientist (Jülich) Dr. Arnd Kuhn, staff scientist (Jülich) Dr. Roland Bol, staff scientist (Jülich), professor (University of Amsterdam) Dr. Ladi Nedbal, staff scientist (Jülich)

Proposed cluster participants at Palestinian universities

Dr. Rami Arafeh, researcher (Palestine Polytechnic University) Dr. Momen Sughayyer, professor (Palestine Polytechnic University) Dr. Nawaf Abu Khalaf, professor (Palestine Technical University Khadouri) Dr. Hazim Albakir, professor (Hebron University) Dr. Aziz Salameh, professor (Al-Quds Open University) Dr. Zaher Al-Barghouthi, deputy director general (Palestinian National Agricultural Research Center) Dr. Amer Kanan, professor (Al-Quds University) Dr. Mazin Qumsiyeh, director (Palestine Institute for Biodiversity and Sustainability, Bethlehem University)

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Scientific content of proposal (max. 5 pages)

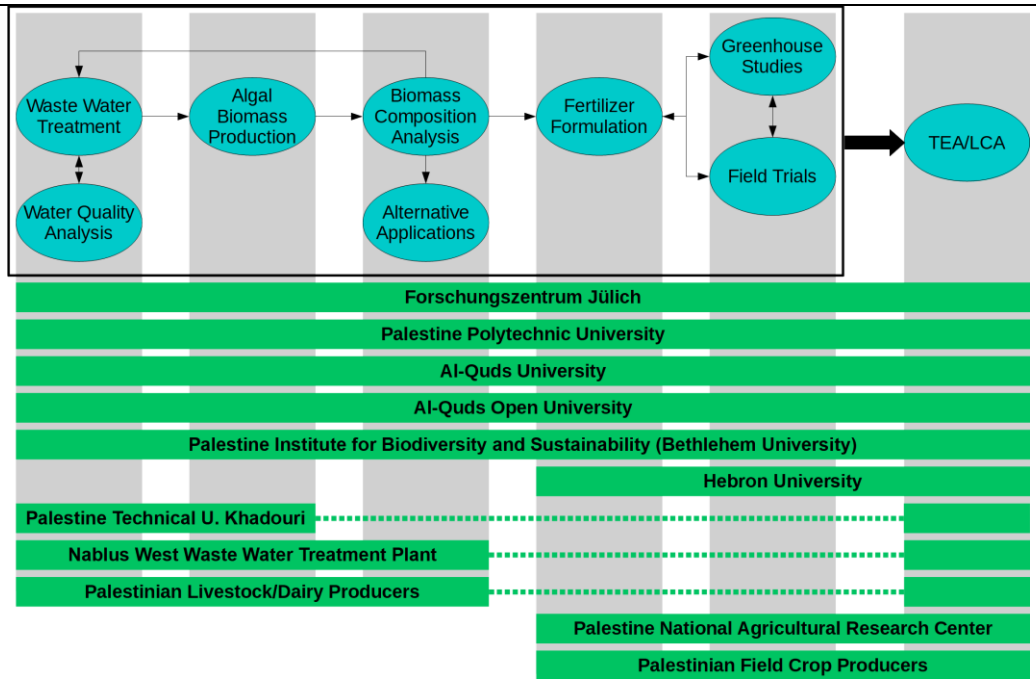
Which fields/research topics can/should be included in this cluster, how do they fit together?

The following topics fit together as part of the chain from wastewater → algae → fertilizer → soil → plants: Algae isolation and cultivation using waste water and algal turf scrubbing (ATS) / algal biomass composition / nutrient composition of wastewater and treated water / contaminant analysis of wastewater, treated water and algal biomass / algal biomass harvesting and processing / algal fertilizer and soil amendment application and assessment / plant growth, health, and yield studies using algal fertilizer / algal biomass as soil amendment / marginal land and ecosystem restoration using algal biomass / alternative uses for algal biomass / life cycle and techno-economic analysis / other by-products from algae-based wastewater treatment

Current activities in this field / results achieved from already existing cooperation projects

Workshops held in Jülich, Hebron, and Bethlehem / Ongoing Palestine Museum of Natural History (PMNH) ATS pilot demonstration / Jülich WWTP ATS Pilot / Additional ATS construction at FZJ / proposed construction of large scale ATS facility at a dairy farm / Existing lab-scale ATS at Palestine Polytechnic University

Please prepare a sketch/model of how this cluster would help toward creating a scientific infrastructure in Palestine, as well as lasting cooperation between researchers in Jülich and Palestine. Please address all points in the call text. If possible, please include a graphic representing your idea.



Proposal Abstract

We propose a research cluster based on exploiting algal turf scrubbing (ATS) to recycle agricultural nutrients from waste water. ATS is a proven, low-tech algae cultivation technique that facilitates proliferation of native algae in an artificial stream rather than using failure-prone, infrastructure- and labor- intensive systems to cultivate defined algal strains. ATS will be used to provide two products from waste water: algal biomass and treated water. The biomass will be used to formulate algal fertilizers and soil amendments, fixing carbon and recycling nutrients that would otherwise

contaminate ground and surface waters or require alternative treatment. The treated water will be used for irrigation or returned to the hydrology network, replacing or diluting polluted water with clean water and thus improving environmental health. The product of the research cluster will be a network of experienced practitioners and accredited academic resources at all levels, from operator/technician to research scientist, along with techno-economic and life-cycle analyses enabling progression from pilot studies to full-scale implementation. The research infrastructure will be able to oversee and facilitate expansion of ATS-based water treatment and algal fertilizer production, and would also be positioned to establish new programs for treatment and biomass production using additional inputs such as black water and industrial waste.

Research Topics

The goal of this project is to demonstrate closing nutrient cycles by producing treated water and algal fertilizer from various types of polluted or nutrient rich waste water and using the fertilizer to grow crop plants relevant to the Palestinian agriculture sector. Each step of the process needs to be optimized and validated in the environment for which it is meant to be used. Thus there are several research topics, depicted as ovals in the figure, with arrows depicting which topics inform the others, and bars depicting which institutions participate in which topic.

The first research topic is evaluation of ATS performance at pilot scale as a treatment practice using waste waters of contrasting origins under real-world conditions: secondary sewage and animal washing waste water. Additionally, the pond at PMNH, while not technically waste water, is an example of nutrient-rich surface water that could benefit from polishing. By monitoring the effectiveness of the treatment process (the second research topic), both by sampling and laboratory analysis and developing an integrated sensor network, we will optimise our operational protocols with the intent to achieve as complete a treatment level as is compatible with the third research topic, that of producing algal biomass with a desirable composition at high productivity (the fourth research topic). These first four research topics will be evaluated with the intent to harmonize wastewater treatment and biomass production for maximum net benefit. An important aspect of biomass composition analysis will be determining the concentration of contaminants that could make the biomass unsuitable as a fertilizer, thus informing a fifth research topic, covering alternative methods for utilizing contaminated biomass, such as remediating it or using it for non-agricultural purposes such as bioenergy production.

The sixth research topic is to develop procedures for formulating algal biomass into an effective biofertilizer or soil amendment. This goal informs and is informed by the seventh and eighth research topics, greenhouse studies and field trials including analysis of plant growth and health and nutrient analysis of both plants and soil. ATS biomass is non-specific and changes in composition with water chemistry and environmental conditions, and so needs to be evaluated over a complete algae growing season. Methods for drying, storing, blending, homogenizing, amending, pelletizing, and in general producing a material acceptable to farmers will be developed within this research topic. In particular it will be important to go beyond considering algae biomass as merely a fertilizer input, as it also contains substantial organic carbon and will likely also contain substantial quantities of diatoms and mineral particles adsorbed from suspended solids. Thus, additional options such as producing compost or biochar from the algal biomass will be considered, as well as the effectiveness of using algal fertilizer, compost, and biochar to reclaim marginal or formerly arable lands.

The ninth research topic is to perform life cycle and techno-economic analyses for the two waste water scenarios, as these will be necessary help define site-specific concepts for expanding ATS throughout the region to perform comprehensive treatment and nutrient recycling utilizing these types of waste waters. Research topics 1-8 will be performed in a way to ensure that appropriate data is collected to effectively inform these analyses.

Completion of these research topics and developing an accredited academic program from the bachelor to the doctoral level will allow the Palestinian partners to take increasing leadership roles in all aspects of the project, expanding into production scale projects and tackling the recycling of additional waste water types until every conceivable niche where this process can work is filled.

Infrastructure needs and how they can be met

Several classes of infrastructure are needed:

1. To perform pilot studies of ATS algae cultivation, the basic requirements are space to build a 0.5 × ~30 m floway (or longer, funding permitting), tank or reservoir volume able to contain several cubic meters of the water to be treated, reliable continuous electric power to operate pumps, and site safety and security. To influence growth rate and pH, availability of CO_2 with the ability to automatically sparge it into the reservoir or along the floway under pH-stat control is required. Multiple sites should be chosen, each with a different type of water. Currently a pilot exists at PMNH for treating what is essentially natural surface water from a pond; this pilot needs to be upgraded. A concept exists for treating wastewater from animal washing at a cattle facility; this pilot needs to be implemented. A third water type is secondary sewage from a waste water treatment plant, which will be available at the Nablus West WWTP. To meet these infrastructure needs, agreements with partners need to be secured as well as funding for construction of the apparatus, generally from materials available from home improvement stores, with a small amount of professional equipment such as high-reliability pumps. One committed part-time operator would is necessary to manage each floway, performing harvest, biomass processing, water sampling, and routine maintenance. This person would need to be adaptable, highly skilled and able to work independently either a technician or a graduate student from one of the participating Palestinian universities.
2. To analyse the elemental composition of the biomass, soil, and wastewater, ICP-OES, Atomic Absorption Spectroscopy, and an Elemental Analyser should be available. Handheld pH, DO, and EC meters should be available. Routine wastewater analyses such as standard spectrophotometric kits for phosphorus and nitrogen species, as well as the ability to assay for pathogens such as coliform bacteria, BOD/COD, and turbidity should be available, as well as general laboratory analysis capabilities for manual analytical chemistry. A muffle furnace or bomb calorimeter should be available for assessing the energy and ash content of the biomass. A high-quality microscope should be available for taxonomic analysis. Some of the necessary equipment is already available at participating institutions, additional equipment would need to be acquired.
3. To process the harvested biomass, some area is needed for solar drying, as well as oven space for drying to a constant weight. Equipment is needed for formulating the algal biomass into fertilizer, such as a grinder or ball mill, mixer and pelletizer. This equipment should be able to handle kilograms of dried biomass per run. Packaging, such as heat-sealed plastic bags and temperature-controlled storage volume for a full growing season's worth dried and powdered biomass will be needed in order to support blending of biomass with varying composition.
4. To perform controlled experiments for using algal biomass as a component of fertilizer, greenhouse space is required for hundreds of pots, as well as field testing plots for similar or even larger numbers of plants, along with the required infrastructure for analyses of the plants and soils.
5. Permitting or approvals may be necessary both for water withdrawals and for discharging the treated water. This process is currently underway with respect to Nablus West WWTP.

Perspectives of our research activities

For FZJ to support education and research at the bachelor, master, and doctoral levels, we envision the following scenarios, supported at the FZJ campus by existing and expanding ATS research infrastructure.

For all studies the student will select or define a research project in collaboration with FZJ and Palestinian cluster members. This project will be designed to provide the student with experience in one or more areas of ATS operations, such as daily monitoring of the treatment process, harvesting and processing the biomass, analysing the untreated and treated water and biomass, utilizing the biomass in fertilizer/soil amendment formulation or application, or performing plant growth studies. For a bachelors project the research question will focus on some detailed aspect of one of the broader research areas, for example determining the effects on biomass productivity of varying one input while holding others constant. For masters research a broader question will be addressed, such as synthesizing the results of many focused research questions (such as those in the bachelor

research). For doctoral projects, the research question would have to be much broader and more comprehensive, such as integrating results from controlled experiments (such as performed in bachelor and master research) to understand and explain what is observed in less controlled, real-world pilot studies. All students will receive hands-on training in construction, maintenance, and/or operation of ATS for biomass production and waste water treatment.

Our research activities are targeted directly at applications that meet fundamental societal needs. Because ATS is already known as a mature algae cultivation practice used for water treatment, the additional work that needs to be done is to demonstrate practical use of the biomass produced as a by-product of the treatment process by: 1) determining annualized biomass productivity and composition measures; 2) determining minimum treatment effectiveness during the shortest/coldest days of the year; 3) determining contaminant content of treated water and produced biomass; 4) determining procedures for formulating food-grade fertilizer and soil amendments from produced biomass; 5) determining effective algal fertilizer and soil amendment application protocols using greenhouse and field trials; 6) understanding the economics of the entire nutrient recycling chain, including identification of specific areas where targeted research can improve the bottom line.

Meeting the needs of Palestinian Society

Palestinian society is not unique in its need for sustainable agriculture and clean water. It is, however, unique in its geopolitical visibility and potential for demonstrating a complete solution as an example for the rest of the world. Developing a research and implementation network for nutrient recovery from wastewater with partners in the Palestinian university system, and the waste water treatment and agriculture sectors, aligns with many of the sustainable development goals for the State of Palestine. This research cluster will utilize high-tech scientific approaches to demonstrate and validate low-tech algae cultivation approaches to recycle agricultural nutrients and produce clean water from different types of waste. In the process of accomplishing this goal Palestinian scientists and students will participate in all steps of the process, and together lay the groundwork for developing an accredited Ph.D. training program within the Palestinian university system, so that the next steps for fully implementing ATS throughout Palestine can be accomplished locally, expanding into more difficult treatment processes until comprehensive nutrient recycling is achieved. This process should create new self-sustaining educational and commercial opportunities while simultaneously improving the health of the Palestinian environment.

Alignment with research interests in Jülich

Two components of the FZJ mission statement are “Our research helps to solve major problems faced by the world today”, and “We want to be a strong partner”. Both of these statements apply directly to this proposal by creating a sustainable ATS research cluster in Palestine whose purpose is to implement algae-based wastewater treatment for nutrient recovery in the region. This cluster will include faculty in multiple institutions training students and scientists at multiple levels. Coursework including study of algal biology and environmental science including topics in waste water, agriculture and regulatory issues will prepare students for bachelor, master and doctoral thesis work addressing both practical and theoretical issues. Partnerships between Palestinian universities and producers of waste water such as treatment plants or agriculture facilities will provide real-world experience and career paths in an expanding economic sector whose very expansion will provide additional research opportunities. University laboratory facilities will provide the opportunity for students to master ATS construction and operation in a safe environment, as well as to perform controlled experiments intended to understand real-world results and to test new strategies for improving designs and operations. Once production facilities are in operation, the scale of research will increase in order to assess prior techno-economic and life-cycle analyses as well as to begin monitoring the broader ecological and economic impacts of major implementation of ATS. This project provides a virtual laboratory for implementing similar programs in other regions. We will perform similar research and implementation locally for the benefit of the German taxpayer who supports our institution, while also continually seeking partnerships in other regions, with the “Palestinian Model” serving as an example of what can be done.

Steps to create career perspectives for alumni

Jülich: 1) Provide research supervision supporting bachelor, master, and doctoral students in achieving their degrees, qualifying them for positions in a future Palestinian algae-based

sustainable economic sector. Provide opportunities for visiting established Palestinian scientists to expand their capabilities through research in Jülich. 2) Help define future positions, which could be academic (e.g. as part of a future graduate and post-graduate curriculum), commercial (e.g. as staff of start-up businesses such as agricultural service companies specializing in algae cultivation, or photobioreactor construction, operation, and biomass processing), governmental (e.g. as staff of the ministries that oversee these sectors), or as consultants advising academia, government, farmers, or as algae experts assisting treatment plant operators. 3) Continue regular hands-on workshops in Palestine and Germany, transferring technology and knowledge in both directions and helping recruit new students into the program.

Palestine: By teaming with the appropriate Palestinian government ministries, universities, and international organizations, define and satisfy standards to receive accreditation for awarding advanced degrees, including doctorates, in the appropriate field(s), such as algal biology and ecology, waste water treatment, ecological engineering, agricultural sciences, and/or sustainable development. These standards include 1) defining missions and goals; 2) addressing ethics and integrity; 3) defining and delivering the appropriate curricula and student experiences; 4) evaluation of educational effectiveness; 5) demonstrating effective planning and resources; and 6) effective governance, leadership, and administration. The accreditation process must satisfy the needs of all partners and students. As there are potentially multiple accreditation organizations, it will be critical to select one with appropriate reputation and prestige.

Opportunities should be made available for alumni to participate as professors, instructors, and/or research assistants (universities), as aides or advisors (government), or as key personnel in ATS related business start-ups (commercial). Programs and information should be made available for technology and skill transfer from the academic sector to farmers, waste water treatment plant operators, and regulators. Outreach to elementary schools and the general public should depict possible jobs and career paths in both the academic and agricultural components of the program.

Please share any ideas for possible funding sources for the cluster, including any joint funding proposals that are being planned/submitted.

Suggested: ***Venture capital***: Palestine Investment Fund / Invest Palestine / Siraj Fund Management Company / Bank of Palestine / Agence Française de Développement ***NGOs***: The Global Environment Facility / Palestine Agricultural Relief Committees / Near East Foundation / Palestine National Agriculture Research Centre (NARC) / United Nations Development Programme – Programme of Assistance to the Palestinian People / Ministry of Agriculture and Rural Development / International Fund for Agricultural Development / datuma.ch / Green Climate Fund ***Government***: Ministry of Agriculture and Rural Development / Ministry of Environmental Affairs / Norway in Palestine.
Submitted: FZJ has coordinated a Phase 1 proposal to Horizon2020 that includes substantial ATS work in Palestine.

Signatures

Representative of research cluster in Jülich (if applicable)

Date	Name	Signature

Representative of research cluster at Palestinian University (if applicable)

Date	Name	Signature