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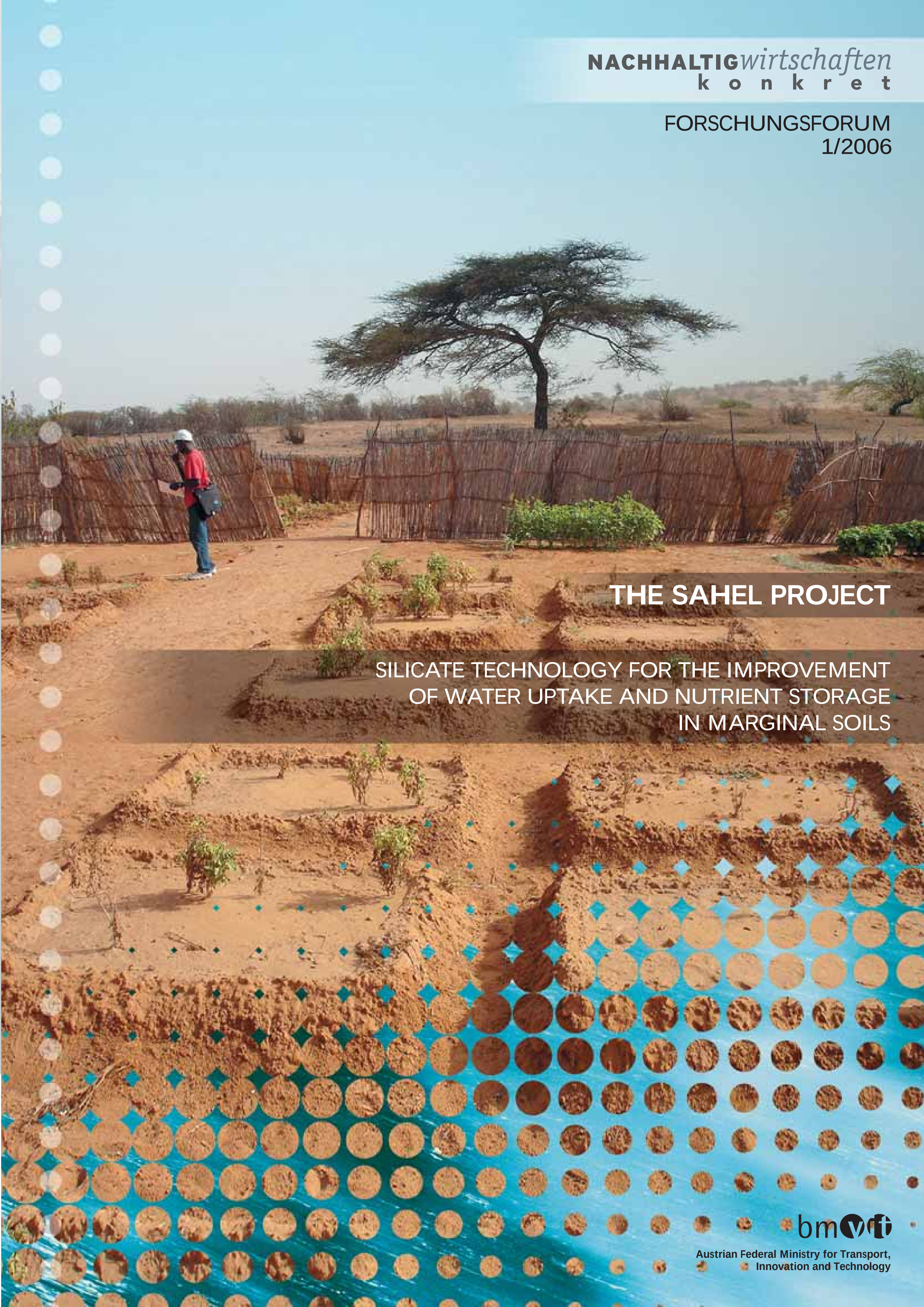


THE SAHEL PROJECT

SILICATE TECHNOLOGY FOR THE IMPROVEMENT OF WATER UPTAKE AND NUTRIENT STORAGE IN MARGINAL SOILS

bmvit
Austrian Federal Ministry for Transport, Innovation and Technology

P R O J E C T

SILICATE-BASED WATER STORING TECHNOLOGY FOR SANDY SOILS IN THE SAHEL

■ The Sahel is a region that stretches across the African continent along the southern border of the Sahara.
It extends over a distance of 4,000 km from West to East and is about 300 km wide. The Sahel countries include Senegal, Mauritania, Mali, Burkina Faso, Niger, Chad, and Sudan. According to recent estimates some 50 million people are currently living in this region.

Major problems in the Sahel include water deficiency, periods of drought, and spreading desertification. This results in conflicts about the use of resources and often migration. Agriculture constitutes the most important economic factor in the Sahel countries; the centers of agricultural production are situated in the southern part of the Sahel and along the big rivers such as the Senegal River. The climate in the Sahel is characterized by a long dry season (8 to 10 months), high temperatures, and little annual precipitation. Rain-fed farming in this region is possible only from August to October. Irrigated farming requires highly intensive irrigation, especially in the hot dry season. Cultivation problems are compounded by the low productivity of soils on account of poor water-storing capacity, low humus content, and extremely low amounts of available nitrogen, phosphorus and other soil nutrients. Progressive desertification (caused by climatic and anthropogenic factors) causes large stretches of land to be lost for agricultural use each year.

Sustainable and future-oriented development is an important element in Austrian R&D activities. In this context, long-term and global aspects have a high priority. The present project is an impressive example of how Austrian research and technology development may contribute to the solution of problems in other climate zones. It was financed jointly by the Federal Ministry for Education, Science and Culture and the Ministry for Transport, Innovation and Technology.

All these factors contribute to a drastically reduced agricultural productivity in the Sahel. However, the growing population has an urgent need for the production of food.

New technologies aiming at soil improvement could contribute to solving these problems. A comprehensive inter- and transdisciplinary research initiative dealing with this topic was conducted within the scope of the "Sustainable Development" activities of the Federal Ministry for Transport, Innovation and Technology and within two FORNE projects (FORschung für Nachhaltige Entwicklung) by the Ministry for Education, Science and Culture.

The **"Sahel Project"** relies on a silicate-based water and nutrient storing technology. The Federal Research Institute "TGM", Building Materials and Silicate Technology / Vienna further developed this innovative technology with a view to practical application and carried out a series of field tests in the northern Sahel region in Senegal to optimize the technology. The results from practical application were evaluated in a statistical analysis (Project Leaders: Prof. Dr. Hugo Hubacek, Dr. Katharina Zwiauer).

The water-storing substrate developed in Austria is a soil improver that helps to significantly increase yields in vegetable crops cultivated in the region. The project has shown that adding the new silicate substrate increased the amount of plant-available water stored in the soil by a factor of 8. This treatment makes it possible to do irrigation farming with relatively low water requirements in these problematic regions, too.

In addition to addressing technological questions the project also aimed to investigate various preconditions for the application of the new technology in the region. It turned out that ethnological and sociological issues as well as transdisciplinary and transcultural approaches constitute important prerequisites for a successful transfer of technology.

R E S U L T S

TECHNOLOGY DEVELOPMENT AND RESULTS FROM THE FIELD TESTS

Research work aimed to develop a substrate that improved the water-storing capacity in very dry soils and makes the water available to plants. In addition, the substrate also increases the storing capacity for nutrients. Thus it is possible to substantially increase the yield of sandy soils with a poor productivity. Originally, the technology was developed for uses in arid areas, but it is suitable for other applications, as well (e.g. dry soils in Europe, wine and fruit growing).

THE PRINCIPLE OF ACTION

From the perspective of physics we can distinguish two types of soil: Sandy soils cannot store water, however, they have a large volume of air-filled porosity. Sufficient aeration of the soil is needed for germination, root growth, and the micro-organisms. Loam and clay soils, on the other hand, draw up water by capillary action and store large amounts of water while the volume of air-filled porosity is very small in these soils. The objective of technology development was to find a soil improver that creates an optimal water-air ratio in sandy soils.

The new silicate substrate is capable of storing very large amounts of water; it expands by several thousand percent of its mass as it takes up water. However, water uptake does not take place in a system of capillaries but rather in a multitude of isolated spots. This means that water is stored in very small particles instead of being distributed in the soil by means of tiny channels and that most of the air volume is retained in the soil.

Three types of force are acting around the water-storing substrate particles:

- Gravitational force (i.e. the water tends to flow off)
- Electrostatic surface force of the substrate particle (i.e. the water adheres to the surface of the particle)
- The suction force in the roots (i.e. the water is drawn up by the plant and into its cells)

The special formula of the water-storing substrate is adapted to this composition of forces. When applying the substrate in the soil only little water runs off, because it is retained by the attractive force of the particles. However, this attractive force is designed in such a way that the suction power of the plant is still strong enough to take up sufficient quantities of water (plant-available fraction of water).

LABORATORY TESTS

The effectiveness of the water-storing substrate has been proven not only in the field tests and the analyses of soil samples from the region; it also was confirmed in laboratory tests based on the “pF-value”. In these laboratory tests plant substrate is saturated with water and a negative pressure (moisture tension) is applied. In a pressure range of 60 to 3,000 hPa the test measures – for different fractions of silicate powder added to the substrate – how much water is given off again. In this pressure range plants are able to take up water from the soil. The laboratory tests have shown that the plant-available water fraction in the soil was increased by a factor of 8 compared to the same substrate without silicate technology.

Eggplant – experimental planting

The ***diagram*** shows the relation between the proportion of silicate powder added and the quantity of water yielded in this pressure range (silicate is given in grams per liter of plant substrate). It permits to ascertain, for different soil conditions, the amount of silicate needed to attain optimal water uptake by the plant.

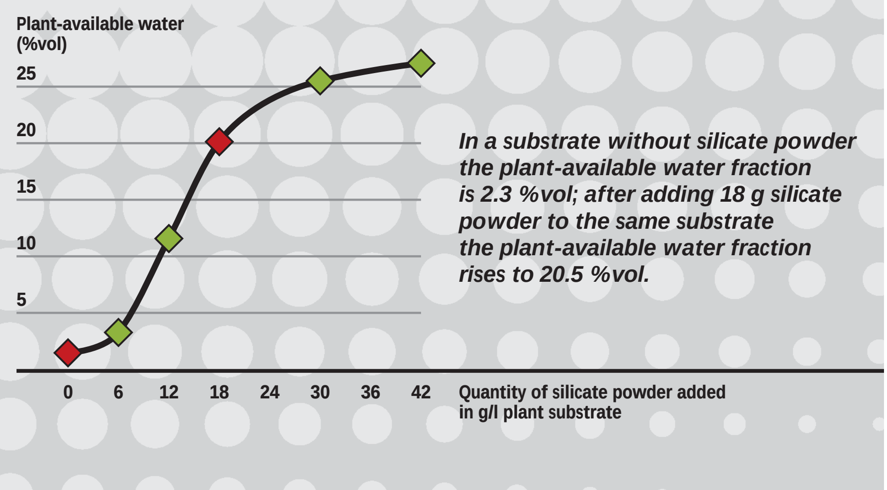
TEST SERIES RESULTS

The overall duration of the project was four years. Four field tests, each extending over several months, were carried out at two locations.

The investigation focused on the questions below:

- What is the water-storing substrate’s effect on yields in combination with varying irrigation rates and amounts of fertilizer used?
- Can losses in yield caused by salt stress be avoided by using the silicate technology?
- For which applications (farming, reforestation, fruit trees) and plant species can the silicate substrate be used?
- In which types of cultivation is the use of the substrate economically viable?
- How can vegetable cropping and the use of the silicate technology be integrated into the traditional labor organization of livestock breeders?

Relation between amount of silicate powder added and quantity of water yielded



Source: Institut für Kulturtechnik und Bodenwasserhaushalt

One phase of the project realized in Austria focused on testing various carrier materials for the substrate as well as different mixtures and corn sizes; additional tests analyzed materials occurring in the Sahel region. There was, however, resistance among users on account of the coarse texture of the material. They disliked the idea of working "stones" into the soil. Finally, an adapted powder was mixed with sand in a certain ratio and the mixture worked into the soil. This simple method proved successful in practice and was well accepted by the users.

In selecting the experimental plants the preferences of the local population and seasonal effects were taken into account. Some 15 different vegetable species such as tomatoes, beans, beets, eggplants, corn, etc., but also local crop plants e.g. bissap were planted for the test series. The researchers then documented and statistically evaluated the cultivation outcomes. The field tests have shown that the water-storing substrate can be successfully used in almost all plant species.

The test series used varying irrigation and fertilizer rates, different qualities of water (saline and river water), various planting methods as well as varying amounts of silicate substrate. Testing in the control groups was performed under the same conditions, but without the use of silicate substrate. Results obtained so far have generally shown that in conditions where losses in yield on account of water deficiency, poor water quality, reduced vitality of plants, wind loads etc. have to be expected the new technology promises to improve yields. In Ourourbe, for example, where ecological conditions are very unfavorable, using the substrate afforded yield increases from 100 to 200 % compared with the control group.

Analyses of woody plants have shown that the use of silicate substrate usually results in higher growth rates and in a much earlier onset of the bearing period in fruit trees such as cashew.

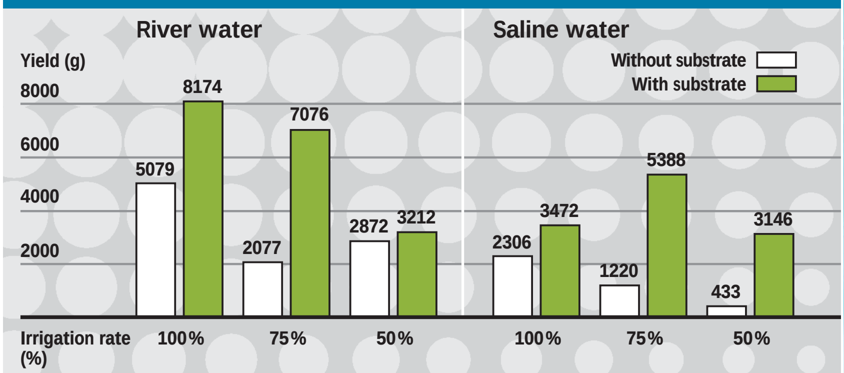
A number of soil analyses have proven that the use of silicate substrate improves not only water uptake but also nutrient-storing capacity:

- Availability of potassium, phosphorus, and other nutrient salts is significantly better.
- Retention of fertilizer nutrients is improved.
- Cation exchange capacity (CEC) is improved.

In addition to questions concerning the new technology many other issues relating to cultivation were discussed with the village population. A vivid exchange of information concerning suitable cultivation methods took place between researchers and the local population. In this process the local project participants were able to acquire new competences concerning more efficient soil tillage and irrigation methods, soil improvement, and adequate fertilizer application.

Source: Vienna Knowledge Net

Yield increases through silicate substrate in field tests (Jaxatu) at Ourourbe



The tests have shown that the use of silicate technology under the given conditions makes it possible to irrigate salt-tolerant and moderately salt-tolerant plants, respectively, using slightly saline water (3.2 mS/cm; SAR: 26) without causing yield reduction.

PREREQUISITES FOR SUCCESSFUL IMPLEMENTATION

In order to ensure that the population in the regions accepts and adequately uses the new technology on a long-term basis the special social, economic, and cultural structures of the region had to be analyzed and taken into account. The local population had to be given the opportunity to participate in planning and the technology had to be adapted to the special needs of the users in order to achieve acceptance and long-term success. For this reason the project not only aimed to optimize the technology, but also investigated sociological and ethnological issues.

Field research was conducted in two villages in northern Senegal:

In **Mbakhana**, on the western part of the river and near Saint Louis, the majority of the population lives off vegetable crops. They cultivate crops in family gardens mainly for the local market and for their own consumption. The families, especially the women, wish to grow vegetables on the sand dunes at some distance from the river as well because these areas are close to the village and can be irrigated relatively easily. However, soil fertility and, in particular, water-storing capacity are quite poor here.

In **Ourourbe**, a village on the edge of the Ferlo semi desert, researchers cooperated with nomad women. This region is inhabited by the **Fulbe**, an ethnic group traditionally living off animal breeding; they hardly have gathered any experience in cultivation methods so far. The Ferlo is characterized by extreme water deficiency. The situation is further compounded by the poor water quality in many wells. The original vegetation has almost completely disappeared. This created a situation where people were hardly able to feed their animals and the remaining vegetation is now exposed to a particularly high grazing pressure. These circumstances made the women wish to create a second source of income in vegetable cropping.

On both experimental sites agricultural productivity is rather low: Major problems include dryness, varying precipitation, low nutrient content of the soil, wind as well as intense pest infestation. Improving agricultural yields could afford a sustainable improvement of the income and nutritional situation for these two groups of the population.

Cooperation with the project participants in Ourourbe has shown that for this group the **principle of joint property** is an important factor that has to be taken into account. Peoples' activities take place in a framework of expansive kinship networks, which also include neighboring villages and far off members of the family. Within this community people mutually support each other and share any economic gain. Even if this practice of sharing is incompatible with our economic way of thinking, it is absolutely necessary to retain this form of social organization in the present situation.

Hierarchical structures in the communities concerned (old – young, man – woman), too, play an essential part, as they are relevant for decision-making processes and the acceptance of the new technology.

In addition, the specific **time structures** and the everyday **labor organization** of the population had to be considered, especially in Ourourbe. The nomad women found time organization to be a major problem. Therefore, one group was trained and was then able to pass on their knowledge to other women. Subsequently, the women who were present looked after the garden. This type of labor organization involved a large number of women who also identified with this new line of production; it also enabled them to retain the migration patterns they were used to.

In Mbakhana, where almost all families had grown vegetables before, there was **resistance against the use of the new technology** at the beginning of the project. However, there were many constructive discussions and a vivid exchange of experience concerning various cultivation methods. Thus, the project team gathered valuable information and was able to adapt the technology to the special needs of users. The method that has finally been developed, i.e. mixing the silicate substrate with sand met with approval among all project partners.

IDENTIFYING POTENTIAL APPLICATIONS

Results achieved so far are quite promising in many respects and confirm a number of possible applications in dry areas, be it in Africa, India or the Middle East. The technology optimization process has now been largely completed and yielded an easily applicable water- and nutrient-storing substrate, which is capable of substantially increasing yields in vegetable crops cultivated in arid areas. In woody plants (reforestation, fruit trees) the silicate technology can also improve productivity (increased growth rates, earlier bearing period). The method is very simple; it is similar to the application of fertilizer and can thus be easily implemented on site by the local population.

There are also potential applications in areas with intensive agriculture in Europe, Canada and the U.S.A that are subject to water deficiency, soil degradation or else secondary salinization.

On account of very promising results in the field of "irrigation with saline water" a series of new field tests will be realized. The need for innovative solutions in this field is particularly great given the fact that the deterioration of water quality and secondary salinization of soils progresses dramatically in arid areas.

On the basis of existing results and a sociological evaluation it is also planned to integrate this approach – together with local partner organizations – into existing international programs such as those by the FAO (**F**ood and **A**griculture **O**rganisation of the United Nations) or the World Bank's "**G**lobal **E**nvironment **F**acility Program" (GEF) and thus achieve a successful implementation.

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