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Bridging science and development: lessons learnt from two decades of development research

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Abstract This paper presents the theoretical, operational and implementation premises that guide the development research agenda of the Center of Development Research (ZEF), exemplified by three agroforestry-related case studies. First, the importance, assumptions, conditions and priorities for development research in the context of developing countries are reviewed. Second, the three core premises of ZEF's research approach, (1) transdisciplinary to carry out research on real-life problems, (2) symmetrical partnerships with local stakeholders to sustain ground activities and ensure implementation, and (3) capacity development to warrant future competences, are exposed. Third, these premises are exemplified and mirrored in three agroforestry-related case-studies: (1) slash-and-burn agriculture in the Brazilian Amazon, (2) socio-ecological management of coffee-agroforests in Ethiopia, and (3) afforestation with multipurpose tree species in Uzbekistan. The paper concludes by streamlining the theoretical and practical premises exposed with the presented case-studies, and confirming how these have guided ZEF in the planning, implementation and continuation of development research programs. Although ZEF's approach to development research is dynamic and continuously subject to assessment, its core remains guiding even after two decades of implementation, appearing to be a suitable pathway for reaching development objectives.

Keywords Development research · Interdisciplinary · Transdisciplinary · International partnership · Capacity building

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Introduction

Scientific knowledge and technology production drive socio-cultural and economic progress. This is the underlying assumption that has guided discourses and policies in the field of Science, Technology and Innovation (STI) Governance in the past 40 years. A good example is the decision of World Bank President James Wolfensohn to rebrand the Bank from a 'lending bank' into a 'knowledge bank' in 1996 (King

and McGrath 2004; Hornidge 2012). Emphasis is placed on three modes through which STI are thought to contribute to development: (1) through the generation of understanding that supports knowledge-based decision–making; (2) through providing technological or social innovations as solutions for existing challenges and enabling their use; and (3) through academic capacity development, regarded as a cornerstone for self-determined development. However, achieving a developmental impact in the sense of providing solutions for specific challenges across the successive steps, such as conception, generation, testing, validation, implementation, evaluation, etc., requires insight not only into the role of science for development but also into its 'how-to'. Here, the Center for Development Research (ZEF) of the University of Bonn in Germany has a critical role to play.

From an economic development perspective, science is often considered as a means of structural development of the economy. In developing countries, the benefits derived from applying technology-oriented research are considered key factors for economic growth (Lundvall et al. 2009; Conway et al. 2010). To achieve this, most governments aim at the construction of knowledge systems/structures that resemble those of knowledge-based economies (Drucker 1993; Evers et al. 2006; Hornidge 2011) where governments promote applied technological research by encouraging inter-linkages between the public (academia) and private (industry) sectors across the innovation process (Edquist 2006; Lundvall et al. 2009) to produce merchandise and knowledge generators of wealth.

But beyond triggering economic development through, for instance, switching from exporting raw materials towards exporting knowledge-intensive goods and providing services, science is challenged when envisioning the future (Sardar 2010). Accordingly, decision-makers can with their actions today provoke long-term consequences and thus act as carriers of change and development (Conway et al. 2010; STEPS Centre 2010). How empirically based knowledge prompts political decision-making is exemplified by the concept of 'integrated water resources management', underlining that through close interaction of well-informed policymakers, scientists and users, development can be triggered (Borchardt et al. 2016).

Science contributes to development on a practical level as well by providing evidence-based solutions to specific developmental challenges. In principle, research can address any type of challenge—social, environmental, economy-related—through a wide range of technological as well as institutional and social options and innovations (Goldberg et al. 2011; UNESCO 2015). An example in this context is the search for a crop/variety to tolerate dry, waterlogged, saline or nutrient-poor soil conditions, or infestations and infections by pests and diseases. Yet, any new technology needs to be embedded into the overall social-ecological system in order to make sense locally and thus be taken up by decision-makers. For that, holistic, inter- and transdisciplinary research approaches are increasingly taken (Nowotny et al. 2001; STEPS Centre 2010; Hornidge et al. 2011; Scholz and Steiner 2015).

Despite theoretical and methodological advances in systemic and problem-oriented science for development, it remains challenging to ensure that research on developmental issues actually takes on the shape of development research, i.e., research that through the participation of local decision-makers and stakeholders becomes transformative research contributing to a desired change—which has to be defined by the stakeholders and the researchers together (Maselli et al. 2006; Douthwaite et al. 2007). For example, when applying agroforestry principles for rehabilitation of degraded land, a major challenge is to jointly develop recommendations and plans for action with stakeholders that fit the local governance system. Even if research outcomes are technically appropriate, final users may not adopt them because of socioeconomic or institutional constraints. Furthermore, policy- and decision-makers might not agree with the required adjustments in the governance structures and object to the implementation of new practices (Appadurai 1990; Marglin 1996; Douthwaite 2002; Siddiqui et al. 2003; Sanginga et al. 2009).

In summary, three principle conditions have to be met to make science for development happen: (1) on the level of international and national science governance, science for development has to be at the center of spending and has to embrace problem-solving, inclusive and pro-poor approaches (Sarewitz et al. 2004; STEPS Centre 2010; Arocena and Sutz 2012); (2) on the level of research design and implementation, conscious and long-term partnering with political

and economic decision-makers and stakeholders, as well as the joint planning and implementation of research and thus knowledge production, has to be guaranteed (Stöckli et al. 2012); and (3) in the realm of political, economic and civil society governance structures, interest and trust in the value of cooperating with scientists for 'better action' has to be nurtured.

In the following sections, the concept of development research is discussed, insights into how it is designed at ZEF, and examples of how it was operationalized in agroforestry-related case-studies are given.

The center for development research (ZEF)

The paradigm of development predominant until the 1960s emphasized the stimulation of economic growth and equity (Schumpeter 1934; Solow 1956; Rostow 1960). But later in the 1970s and 1980s, offsets were acknowledged, such as its restrictiveness and narrowness, and long-term effects on natural resources, as well as changes in demography, urbanization, democratization and trade, which made adjustments necessary (Meadows 1972; Brookfield 1975; UN 1980; Bartelmus 1986; WCED 1987). Hence, underlining ecological sustainability, the concept of sustainable development was coined (WCED 1987). Later, self-determination, rights, cultural identity, information and participation were progressively incorporated (UN 1992, 2000, 2002, 2012), and today these multiple demands are systematized in a global agenda with specific objectives, i.e., first the Millennium Development Goals (UN 2002) and more recently the Sustainable Development Goals (UNDP 2015).

As an answer to development dynamics, in 1995 ZEF was established aiming "(…) to capture and move beyond the best current research and teaching on development" with the mandates to (1) produce and disseminate development research to reduce poverty and enhance sustainable development; (2) improve development policymaking and support collaborative research in and with developing nations; (3) build capacities for research, policy analysis and policy-making; and (4) disseminate research results beyond the scientific community" (ZEF 2001, 2007).

Since its foundation, ZEF has aimed to move beyond compartmentalization, and has transited from multi-, to inter- and lately transdisciplinary approaches. These are implemented through integrating different bridging mechanisms between science disciplines, research and policy research and practice (Mollinga 2008, 2010). This approach permits not only confronting complex problems on development, but also communicating findings to scientists, politicians and practitioners, thus triggering the mechanisms of implementation and facilitating the achievement of intended goals (Table 1).

However, ZEF does not aim at research around cross-cutting themes only. Whenever it is appropriate, integrative research is conducted on the basis of solid and rigorous disciplines. Hence, ZEF research areas are determined by three disciplinary domains that are mirrored in its departmental structure: (1) *Political and Cultural Change* (ZEFa) is engaged in the analysis of institutions, knowledge and governance of societies, and how these are involved in the administration of the environmental change and human development; (2) *Economic Development and Technological Change* (ZEFb) studies mechanisms to surmount poverty and achieve equity and welfare in societies through economical and market-related infrastructures and tools; and (3) *Ecology and Natural Resources Management* (ZEFc) focuses on the use of natural goods, products and services, their impacts and depletion, and the identification of viable mechanisms for their rehabilitation and sustainable use. Key crosscutting research questions in this scheme are: How are economic policies to be structured to foster growth, poverty reduction and the sustainable use of natural resources? How can natural resources be allocated to accommodate rural, urban and industrial requirements without jeopardizing resource quality and restoration? Finally, how can the implementation of policies be improved to ensure the achievement of the desired goals? (ZEF 2001, 2007, 2015) (Fig. 1).

ZEF is also strongly engaged in capacity building to implement and transfer its view on development research. Founded in 1999, the ZEF Doctoral Studies Program (DSP) trains scientists and decision-makers from all over the world and, through them, implements selected studies. ZEF projects often involve multi-level capacity development components, thereby strengthening and creating local scientific infrastructures.

With a turnover of 25 doctoral candidates per year, to date 570 individuals have participated in ZEF's DSP, two-thirds of these from developing countries,

Table 1 Main integration domains of ZEF's research strategy *Source*: ZEF (2001, 2007, 2014a, b)

Across disciplines	Between research and policy	Between research and practice
Bringing together diverse knowledge, approaches, methodologies and methods	The political context is determinant for the type and focus in the production of research	Betterment of living conditions is the ultimate goal of development research
Permits more accurate estimations of socio-ecological changes	Research itself is often part of a political process, since it adjusts its goals and time frames based on different premises	The quality of research is valued not only by its relevance but by its operational usefulness
Allows addressing trade-offs of surmounting poverty and natural resources use	Hence, communication and mediation is key to delivering research to policymakers	Engaging local practitioners and potential users ensures the uptake of research outcomes
Allows more realistic assessment of the adoptability of research innovations	Media and civil society influence on public awareness and indirectly on policy choices	Including local stakeholders alongside the research process prevents generation of "ivory tower" knowledge, outside reality
Allows more accurate recommendations for the local socio-ecological contexts	Great part of development research is funded by international donors, which obey international politics	

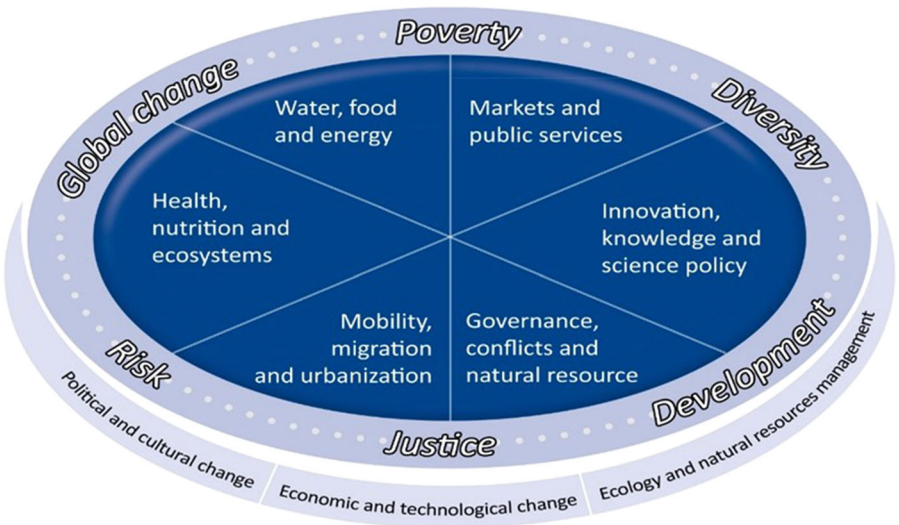

Fig. 1 ZEF inter-/transdisciplinary research strategy: global development objectives (*outer ring*), core research areas (*inner ring*), and departmental organization (*underpinning basis*). (*Source*: ZEF 2015)

who are all part of an active alumni network (www.zef.de/alumni). This network encompasses alumni in key national and international positions in research and policymaking, thus facilitating cooperative initiatives on research, education and dissemination of/in development policies. This is substantiated through the financial support from the German Government, and national and international funding bodies. Since 2009, ZEF has been consistently listed by the University of Pennsylvania among the top five *To Go To Think Tanks* in Science and Technology, as well as among the best university-affiliated think tanks (http://gotothinktank.com).

Although being a university institution, ZEF maintains strong bonds with development cooperation institutions. Carrying out rigorous academic research and

maintaining interactions with operational organizations, e.g., federal ministries, funding bodies, United Nations dependencies and international and national NGOs, ZEF has become an active player in the development 'scene'. Furthermore, ZEF contributes directly through its series of publications of policy briefs and recommendations as a by-product of its research, as well as by regularly hosting policy dialogues.

Agroforestry for development: an example

Besides focusing on broad developmental problems, ZEF has carried out a number of disciplinary and interdisciplinary studies on agroforestry, resulting in about 20 doctoral dissertations and more than 35 publications in form of scientific articles, working papers and book chapters. Beyond that, several agroforestry practices, systems and technologies were core components of larger ZEF projects, i.e., improved fallow practices to substitute slash-and-burn agriculture, socio-ecological management of nature reserves to protect native coffee agro-forests, or afforestation with multipurpose-trees to recover degraded lands and generate wealth.

Chop-and-mulch as a fire-free alternative to slash-and-burn in Amazonian smallholder farming

The slash-and-burn practice is traditionally applied by smallholders for land preparation in forest-based fallow systems of the tropics and subtropics. These systems are agroforestry systems with the temporal integration of woody components such as trees and shrubs. The intensification of cropping due to population pressure or market demand leads in the long run to the degradation of the forest and soil resources upon which the land-use system relies. This occurs mainly through the gaseous loss of nutrients and organic material (carbon) during the burning process (Denich et al. 2004) and the removal of nutrients in form of harvested crops (Sommer et al. 2004). These losses result in a negative nutrient balance of the slash-and-burn system, i.e., more nutrients are removed from than returned to the cropped areas, and as this repeatedly happens, it leads to degradation of the agricultural land and puts the fallow system as a whole under pressure (Denich et al. 2004, 2005; Sommer et al. 2004).

As the removal of nutrients with the harvested crops cannot be reduced, the nutrient losses can only be minimized by replacing the slash burning for land preparation with fire-free technologies. In addition, the fallow vegetation is a source of organic matter that helps to improve the soil properties. Both fire-free land preparation and management of soil organic matter can be combined in a mulch approach. The mulch layer also protects the soil against erosion, preserves soil water during dry spells, and reduces the growth of weeds, and once decomposed, it is a source of organic matter and nutrients improving the soil properties (Kato et al. 1999). Mulching requires that the woody fallow vegetation is chopped into small pieces. Given that manual chopping is labor-demanding and strenuous, the mechanization of chopping was crucial for the introduction of the mulch-based technology and its adoption.

Between 1991 and 2004, ZEF and its German partners at Georg-August-University Göttingen together with the Brazilian Corporation of Agricultural Research (*Empresa Brasileira de Pesquisa Agropecuaria*; Embrapa) developed a mechanized fire-free method of land preparation in forest-based fallow systems in the context of the R&D project *Secondary forests and fallow vegetation in the agricultural landscape of the Eastern Amazon region—Function and management* supported by the German Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*; BMBF; Denich et al. 2005). The comparison of different forest choppers showed the benefits of the forward-moving tractor-propelled machines. They not only cut the woody fallow vegetation just above the ground but also simultaneously chop and apply it as a homogeneous mulch layer. Apart from its benefits to the environment such as reduced greenhouse gas emissions or less accidental fires in neighboring cropped areas, the chop-and-mulch technology increases land and labor productivity and improves labor quality during land preparation (Denich et al. 2005).

Financial analyses show that the chop-and-mulch technology turned out to be an economically viable alternative to the slash-and-burn system. Nevertheless, the farmers' caution against crop failure is one of the main barriers to its adoption by smallholders (Börner et al. 2007). Moreover, mechanized mulching makes manual labor dispensable, and if the freed labor were to be used for additional land clearing, this technology

would result all in all in a negative net effect through a further loss of fallow vegetation and the respective stored carbon (Börner et al. 2007).

A participatory rural appraisal (focus group discussions) revealed that farmers clearly recognized the pros and cons of the chop-and-mulch technology. Pros of the technology are: no back-breaking land clearing, reduced weeding activities, no damage to neighboring plantations by escaping fires, no threat to wildlife, better control of erosion and conservation of soil moisture. Cons are: loss of fuel wood as all wooden parts of the vegetation are chopped, planting is more time consuming because of the mulch layer, walking on mulched fields is unpleasant and injury-prone, and economic costs and benefits are not clear yet (Osvaldo R. Kato and M. do Socorro Kato, Embrapa, personal communication).

The chop-and-mulch technology was developed under the agro-ecological, socio-cultural, economic and political conditions of the Eastern Amazon region. To accelerate the adoption of the research-based approach and integrate it into the land management system of small farmers to ensure the sustainability of forest-based fallow systems, appropriate incentives and policy measures have to be in place. These include reduction of chopping costs, technology-specific crop-yield insurances, taxing slash-and-burn and providing alternatives as well as set-aside payments and payments for the environmental services of forest fallows (Börner et al. 2007). Supportive policies might provide incentives for investors, such as engineering industries or agricultural service supply agencies, to make chop-and-mulch machinery available. Policymakers should recognize that chop-and-mulch represents a potentially sustainable addition to the portfolio of technologies for land management in the Amazon region and a step towards integrating resource use and conservation.

In conclusion, the findings of this interdisciplinary research project underline that the newly developed chop-and-mulch technology represents an ecological and economically viable alternative to traditional slash burning in tropical forest-based fallow systems. Moreover, the project was strongly transdisciplinary, as all research and development work was carried out on smallholder farmland, and the pros and cons of chop-and-mulch were revealed to the farmer from the very beginning. The success of the project was fuelled also by the long-term (13 years) commitment of the donor and other stakeholders, enabling a close and meaningful collaboration of Embrapa and ZEF scientists. In this context, there was a strong academic capacity development component that is reflected in 17 doctoral and 48 master, diploma and bachelor theses completed by young Brazilian and German scientists. The success of the project may also be owed to the fact that the chop-and-mulch technology as an alternative to the slash-and-burn practice was regularly covered in the media (print media, radio, TV), and that video films were produced for dissemination on numerous field days with farmers, extension agents, policymakers, etc. The project was awarded two national prizes (environment and excellent partnership). Embrapa scientists assumed full ownership of the chop-and-mulch technology and continued with the research and implementation work after completion of the project (Shimizu et al. 2014). In the long run, chop-and-mulch has to be seen as a transitional system between traditional shifting cultivation and sustainable permanent cropping in tropical regions.

Conservation and use of wild Arabica coffee in the montane rainforests of southwest Ethiopia

Coffee is one of the most important commodities worldwide and a source of foreign currency for approximately 50 developing countries. Arabica coffee (*Coffea arabica*) constitutes two-thirds of the internationally produced coffee and three quarters of its commercial value. It has its botanical origin in the highlands of southwest and southeast Ethiopia where it still grows naturally as a small tree in the undergrowth of the Afromontane rainforests at altitudes between 1000 and 2100 m (Tadesse 2003; Feyera 2006; Schmitt 2006; Feyera et al. 2007). Agricultural land-use pressure on the forest areas is leading to deforestation and the wild Arabica coffee populations are disappearing along with the forest cover at an alarming rate (Dereje et al. 2008). Wild Arabica coffee is not only a very popular drink and source of income for forest users but constitutes also a highly promising gene pool for national and international coffee breeding (Kassahun 2006; Feyera et al. 2009; Lack et al. 2013).

To prevent the montane rainforests and their Arabica coffee populations from further damage and to promote their conservation and sustainable use, in 2002 a project entitled *Conservation and use of the*

wild populations of Coffea arabica in the montane rainforests in Ethiopia (CoCE), was jointly established by ZEF, partners at Bonn University and Ethiopian partners including the scientific, public and private sector with support from BMBF. Since the research had been initiated by Ethiopian scientists, the Ethiopian ownership of the project was guaranteed from the very beginning. The project aimed at assessing the species diversity of the montane rainforests, the genetic diversity of their wild Arabica coffee populations and the economic value of the Ethiopian Arabica coffee gene pool, as well as at developing concepts for conservation and use of wild coffee together with its rainforest habitat. The respective research was inter- and transdisciplinary, considering ecological and socioeconomic aspects, and involving stakeholders at local, national and international levels (Zander and Moll 2008).

Results have proven that (1) there is a high degree of plant species diversity in the montane rainforests (745 plant species, 32 endemic); (2) forest areas with the occurrence of wild coffee are floristically similar across regions due to ecological factors and management interventions by coffee collectors (removal of competing trees and shrubs; Feyera and Denich 2006); (3) there is a high degree of genetic diversity in wild coffee populations but this differs from region to region (Kassahun 2006); (4) there is a high variability in wild coffee populations related to their tolerance to fungal diseases and droughts (Beining 2007); (5) the potential global economic value of the Ethiopian wild coffee gene pool as a resource for coffee breeding amounts to US$ 0.4–1.5 billion (Hein and Gatzweiler 2006); and (6) there is a conflict of interest regarding the use of forest resources concerning mandate, responsibilities as well as property rights at local, regional and national levels (Stellmacher 2007).

Regarding the implementation of the project findings, an important step was the creation of the Environment and Coffee Forest Forum (ECFF) in 2005, a non-governmental Ethiopian organization intended to link science and politics, to lobby for the conservation and use of Ethiopian forests and wild coffee, to organize practical conservation measures for wild coffee, and to carry out research related to forests and the environment. Most importantly, the forum was to ensure the sustainability of the project's activities beyond its completion in 2009. ECFF developed the concept for a biosphere reserve in the southwest of Ethiopia within the framework of the UNESCO Man and the Biosphere Program (UNESCO-MAB), which formally designated the Yayu Coffee Forest Biosphere Reserve in 2010. Furthermore, ECFF initiated a specialty coffee marketing program called "Darara Buna" (in Oromiffa language: coffee flower) to link coffee producers from the biosphere reserve with high-segment consumers.

In conclusion, the success of the CoCE project lies in its integrative character. An innovative aspect in the context of the biodiversity-related research was the strong focus on implementation. Supported by specialist advice, research findings were identified and structured according to their implementation relevance. This process included analysis of findings, assessment of risks and opportunities, clarification of financing possibilities, and development of a strategy for implementation, and the implementation itself. With ECFF and the biosphere reserve, the CoCE project succeeded in establishing structures to bridge the gap between research and practice and to make research sustainable. Part of these structures was the training of young academics (15 doctoral and 31 master degrees at Addis Ababa and Bonn Universities). Meanwhile, ECFF has broadened its scope and included climate change and food security issues in its portfolio, and remains one of ZEF's most important research partners in Ethiopia.

Afforestation of degraded saline soils in Uzbekistan

The drying up of the Aral Sea in Central Asia caused by the expansion of the irrigated area for crop cultivation is probably the most cited, tragic consequence of unsustainable management of water resources. The irrigation of about eight million hectares in the region, one of the largest irrigated areas worldwide, was accompanied by growing soil degradation (Akramkhanov et al. 2008).

In this context, the challenge was to develop land-use options aiming at land rehabilitation, efficient use of natural resources and enhanced rural incomes. During 2000–2012 and with support from BMBF, ZEF, UNESCO and the State University of Urgench in the Khorezm region of Uzbekistan, conducted a long-term research project entitled *Economic and Ecological Restructuring of Land and Water Use in the Khorezm Region of Uzbekistan: A Pilot Project in*

Development Research. The innovative approach was based on four pillars: (1) providing science-based innovations for improving land and water use; (2) integrating science, research and education at national and international levels; (3) building human and institutional resources in the intervention area and creating a center of excellence; and (4) securing a long-term commitment.

One of the investigated options was built upon the concept of setting aside degraded cropland parcels for ecological restoration through afforestation with salt-tolerant tree species, while intensifying agricultural practices on productive lands for ensuring food security (wheat) and cash income (cotton). Disciplinary studies addressed the bio-physical potential of afforestation including aspects of nutrient cycling and management (Khamzina et al. 2009a; Lamers et al. 2010; Sheer et al.), water use and silvicultural management (Khamzina et al. 2008, 2009b), and utility value of tree products (Lamers and Khamzina 2008, 2010). The research outputs illustrate not only improved land productivity and soil health (Khamzina et al. 2012), but also financial profitability of such an agroforestry strategy (Lamers et al. 2008). When abandoning cotton production, these marginal areas could provide ecosystem services through plantation forestry. In a flanking value chain analysis, it was shown that the processing of cotton fiber into ready-made garments has the potential to reduce land and water use and subsidies by more than 60 % while still providing similar revenues (Rudenko et al. 2008). After examining farmers' perceptions of introducing afforestation on degraded farmlands (Kan et al. 2008), a transdisciplinary innovation research was undertaken that field-tested the adoptability of the afforestation options (Ul Hassan et al. 2011).

Despite the ecological and financial benefits of afforestation, legislative and socioeconomic aspects still hamper a widespread adoption, i.e., legislation for setting aside degraded cropland is missing, land tenure and tree plantation ownership are not clarified, markets for tree products are underdeveloped, farmers have insufficient awareness of the agroforestry benefits, and policy incentives to initiate the land-use change are lacking (Djalilov et al. 2016).

Moreover, in Uzbekistan any farming innovation can be implemented only after the approval of the National Ministry of Agriculture and Water Resources and the Agrarian and Water Management Committee of the Lower House of the Parliament of Uzbekistan 'Oliy Majlis', who need to confirm the scientific validity of the findings, thus setting the beacon for the spread of the innovation (Ul Hassan et al. 2011). Finally, four innovations developed by the project were ratified and the Government of Uzbekistan endorsed their dissemination.

Due to the long-term commitment of the participating stakeholders, the manpower and infrastructure to support, advanced research activities in natural and social sciences were secured. Hence, capacity building was integrated into all levels of the project activities considering different academic levels and safeguarding a gender and minorities balance. Since 2002, 54 doctoral students, about half of them from Uzbekistan, completed their field work in Khorezm. They conducted their research under the supervision of local and foreign academics. A further 105 master and 90 bachelor students from various countries in the region participated, and an extensive alumni network was established (Lamers et al. 2015).

Complementary to these activities, a strong effort went into disseminating findings and preparing training materials for wider audiences. Hence, the GEF (Global Environment Facility) and UNDP (United Nations for Development Program), aiming at mainstreaming global environmental priorities into national development planning and management, invited the project to the 'Presidential Academy', a unique high-level educational institution operating at national and regional levels.

This partnership in research and higher education resulted in the development of sustainable options for the use of natural resources operationally acceptable to farmers and decision-makers, while successful capacity building enabled local stakeholders to take over the project after its completion.

Conclusions

Generating sound science capable of triggering and sustaining development is still a challenge. Its scope and broadness, diversity of stakeholders involved and their diverse and often conflicting interests leave narrow action pathways that prevent universal assertions and 'one-size-fits-all' strategies. However, agreement seems to exist that development needs to be addressed holistically while considering social,

political, economic and environmental dimensions, emphasizing problem-solving approaches but also bearing in mind long-term impacts, and maintaining ties with policy-making instances with the aim to subsequently enforce outcomes.

From its perspective, ZEF advocates a research approach implemented consistently for the last two decades. The approach embraces three main premises: (1) transdisciplinarity as a theoretical platform and as the knowledge repository and means to conduct purposeful, solution-oriented research; (2) symmetrical partnerships with local stakeholders to sustain operational, scientific and logistic field actions, and to secure further up-taking of research findings; and (3) capacity development to guarantee long-lasting, endogenous capabilities for research and education as well as for policy design and implementation of findings. An internal, disciplinary structure comprising social, economic and ecological aspects facilitates the acknowledgement and first handling of research subjects, but ultimately seeks to cover and address developmental issues holistically (Fig. 2).

The three, agroforestry-based case studies mirror the operationalization of ZEF's research approach. For example, research on improved fallow practices in the Amazon went beyond the mere biophysical aspect, but proposed economic policies to complement concepts of sustainable land management. In the project on conservation and use of Ethiopian wild coffee, assessments spanned from the biological to the economic accounting of benefits, passing by the cultural and institutional trade-offs. The study on afforestation in Uzbequistan, not only tested MPT species from biophysical and socio-economic perspectives, but also explored the generation of byproducts and ecosystem services. Moreover, in all three cases efforts were made to elaborate strong partnerships to ensure the implementation of research findings, e.g., by seeking early support from government decision-making bodies, such as the Uzbek National Parliament, or in Ethiopia, via co-founding a local institution such as ECFF, endowed with the expertise to propose and implement large scale initiatives, such as the establishment of a biosphere reserve. Finally, as evidenced by all three cases, the training of scientists was from the onset an integral part of the research program, what resulted in a continuation and follow-up of the research outputs and outcomes and the

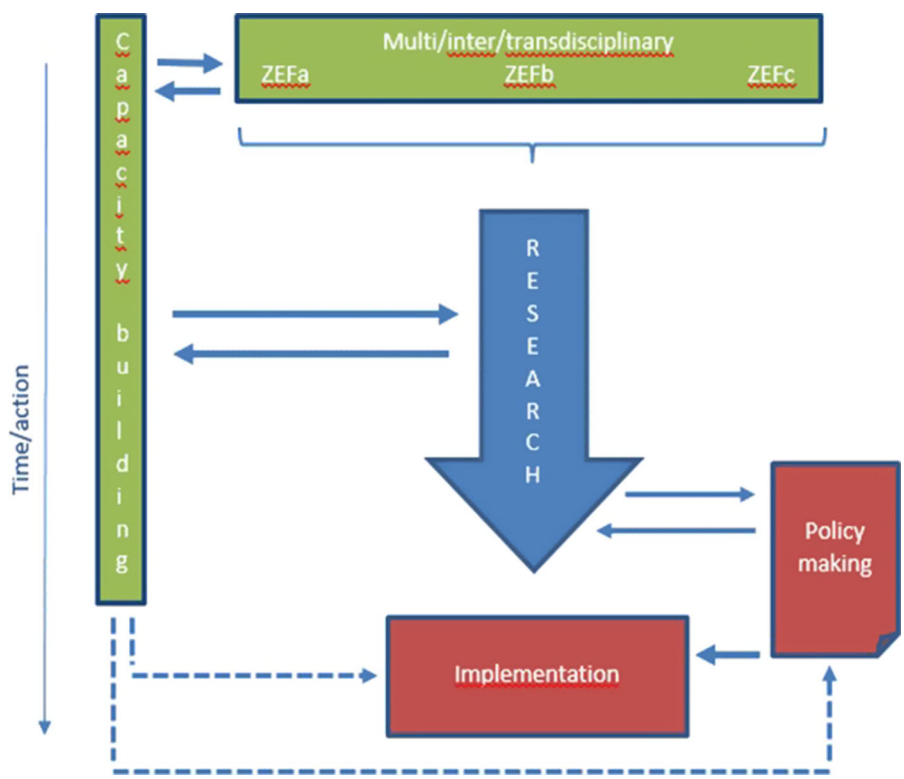

Fig. 2 ZEF approach to development research

consolidation of long-term partnerships after the projects ceased.

The premises of the ZEF approach underpin newer research initiatives, such as for instance the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL), with an envisaged long-termed presence in the 15 West African ECOWAS member countries. It is the aim of ZEF to harmonize WASCAL disciplinary and interdisciplinary research and promote its implementation through an in situ platform of scientific/operational interaction with local stakeholders combined with the training of young academics.

These success stories confirm the progress that can be made through pursuing overarching premises, which for ZEF encompasses inter/trans-disciplinarity, local empowerment and capacity development as these can significantly contribute to initiate change processes in development regions and to make research findings sustainable.

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