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Interim Report **IR-04-007**

Local Knowledge on Ecosystem Management Practices and Human Plague Problems in West Usambaras, Tanzania

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Abstract

The human impact on natural landscapes has been steadily increasing during the last few decades and the current decline of biodiversity is largely the result of human activity. Many of these activities have resulted in a wide range of environmental changes that accelerate and interact with other environmental changes at local, regional and global scales. Ecosystem degradation in many areas of the world has been associated with the increase in the distribution of human plague cases, both land use and climate changes have been suggested as causes of the persistence of human plague in Africa, America and Asia. In West Usambaras, Tanzania, human plague is a public health problem, which has been associated with land use and land cover changes and the level of the spreading of the disease has increased from one village in 1980 to about 48 villages by the end of the year 2002, in the whole district. This case study shows how local people link the anthropogenic modifications of the ecosystems with the frequent outbreak of human plague in the area. Using a case study protocol developed by Initiative on Science and Technology for Sustainability (ISTS), the case study has been expanded to look at the issues such as stakeholder involvement in the development of this case study, the science policy- interface and the challenges of interdisciplinary research for sustainable development.

Preface

The Initiative on Science and Technology for Sustainability (ISTS: http://sustainabilityscience.org) is an international, open-ended network with the goal of enhancing the contribution of knowledge to environmentally sustainable human development around the world. The Initiative was founded in late 2000 by an independent group of scholars and development practitioners gathered at the Friibergh Workshop on Sustainability Science. Since that time, it has worked to strengthen cooperation between two communities: practitioners involved in promoting human development and environmental conservation, and researchers involved in advancing science and technology relevant to sustainability.

One of the aims of ISTS is to "foster the next generation" of sustainability scientists. With this goal in mind, ISTS together with the Third World Academy of Sciences (TWAS) and IIASA, invited three young scientists from developing countries to participate in the IIASA Young Scientists Summer Program (YSSP) for three months in the summer of 2003. The competition for fellowships was very strong, with around 100 applicants for the few places that could be funded. The funding was provided from a grant from the Lucille and David Packard Foundation to ISTS.

The aim of this summer initiative was to help the young scientists expand their case studies on environmental issues to consider the issues of sustainable development. This was aided by a protocol developed by David Cash and Vanessa Timmer and others within the ISTS, which raised questions to guide case studies on harnessing science and technology for sustainable development. Obviously, in three short months, it was not possible to answer all of the questions raised in the case study protocol, but it was possible to tackle some of the

questions in individual work and group discussions. The three IIASA Interim reports from Sharda Mahabir (Trinidad and Tobago), Juan Moreno Cruz (Colombia) and Riziki Shemdoe (Tanzania) demonstrate very well the progress that was achieved

In addition to presenting the results at the traditional mid-summer YSSP workshop, the ISTS/TWAS scholars also traveled to Trieste and presented and discussed their work at TWAS.

I would like to thank Diego Malpede, ISTS/TWAS Research Fellow, who provided untiring support during the application and selection process and for our visit to TWAS. Thanks also to Leen Hordijk and Joanne Bayer, IIASA, for their support in bring these scholars to IIASA and providing a learning experience for all of us.

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His sincere thanks are to his supervisor, Dr. Jill Jager who was always helpful, supportive and provided new ideas from the time he arrived in IIASA to the time he completed writing this case study. Many thanks are due to Sokoine University of Agriculture (SUA, www.suanet.ac.tz) for granting him a permission to attend the YSSP 2003.

The author furthermore acknowledges all scientists at IIASA and others from elsewhere for the useful knowledge that they contributed during different presentations and seminars.

His sincere thanks are due to all YSSP 2003 fellows for their cooperation during the three months stay in Austria. The special thanks go to his wife Rachel as she agreed to allow him to come and attend the three months program at IIASA.

About the Author

Riziki Silas Shemdoe participated in the 2003 YSSP Young Scientists Summer Program at IIASA. He is a IIASA/TWAS/ISTS Scholar from the University of Agriculture, Sokoine University, Tanzania, Africa.

Local Knowledge on Ecosystem Management Practices and Human Plague Problems in West Usambaras, Tanzania

Riziki Silas Shemdoe

1.0 Introduction

1.1 Background information

The human impact on natural landscapes has been steadily increasing during the last few decades. The number of human-caused disasters has dramatically increased in the recent past. Irreversible damage of forest and steppe ecosystems has resulted from indiscriminate tree cutting, overgrazing, military activities and other forms of human impacts on natural resources. Such undertakings have, to a large extent, resulted in ecosystem degradation (Navarro and Waltner-Toews.1999).

Decline in habitat quality and human appropriation of a larger function of total biomass leads to many catastrophic breakdowns (Babier *et al.,* 1994). The current decline of biodiversity is largely the result of human activity. Many of these activities have resulted in a wide range of environmental changes that accelerate and interact with other environmental changes at local, regional and global scales. Moore (2001) concluded that 50% of the land surface has been transformed by direct human action with significant consequences for biodiversity, nutrient cycling, soil structure and biology, and climate. More than one-fifth of land ecosystems have been converted into permanent croplands; more than quarter of the world forests have been cleared. The effects of these are global warming, habitat fragmentation and disruption. Furthermore,

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the environmant is challenged by the introduction of invasive species resulting from urbanization, travel, and globalisation, among others. These represent serious threats to human health and survival.

Ecosystem degradation in many areas of the world has been associated with the increase in the distribution of plague cases. In the United States, for example, plague disease has been attributed to both land use and climate changes (Craven *et al.*, 1993). In Mozambique, epidemics of the human plague have been associated with unusual weather patterns, the irregularity of rainfall and drought in the region, which may be associated with the deforestation (Bareto *et al* 1994). According to Navarro and Waltner-Toews (1999), ecological changes associated with inter-annual climate variability have been associated with rodent infestation in Southern Africa. The West Usambara Mountains is a rural area in Tanzania that experiences a high rate of population growth, i.e. between 2.2 to 3.2% (Inversen, 1991). Human impact on natural landscapes has been steadily increasing and has resulted in the reduction of the vegetation cover in the area. Ecological changes associated with interannual climate variability have been associated with rodent infestation in this area (Kilonzo 1994). Land degradation is common in the West Usambara Mountains. This is attributed to poor land husbandry, increased erosion and decline in soil fertility, and non-/or limited use of fertilizers (Shelukindo, 2000).

The impact of this is a decline in crop yields, increased food insecurity and reliance on food aid, poor nutrition and increased dependence on forest resources for livelihoods. Shortage of land is also reportedly responsible for emigration of some people to the nearby lowlands and urban centres. (Johansson, 2001). Excessive deforestation has greatly influenced the natural resource base in the West Usambara

Mountains. Apart from increased demand for agricultural land due to increased population, shifting agriculture practised in the past and the lack of local people traditions for protection of trees are the principle causes of deforestation. The consequences of such activity are decline in amounts and reliability of rainfall, decline of water levels, increased incidences of run-off, floods, siltation and loss of biodiversity (Huwe, 1988). The impact of this is seen in increasing land scarcity, fragmentation of land into small uneconomical plots, limited attention of parcels of land located far away from households, wide-spread cultivation on marginal lands and encroaching into forest reserve (Jeremias *et.al*, 2002). Based on species-area relationships, such deterioration of original forests suggests that approximately 34 % of plant species in the West Usambara have become extinct or are at risk of extinction (Newmark, 2000).

Human plague is a public health problem that has also been associated with the land use and land cover changes, which have forced the plague-infested rodent to move close to human settlements and as a result increased human-rodent contacts and hence the frequent outbreak of the disease in West Usambaras. The area has been the dominant human plague active focus in all of the East African countries. It has been affected by human plague since 1980 when the first outbreak of the disease occurred in one village. The disease has spread in the district and has so far involved about 48 villages (Kilonzo 2003) out of 162 villages in the district (Nesje, 1999).

Fig.1. A typical village in Usambara mountains, Tanzania

Different studies have suggested possible solutions to the plague problem in the area. Some of the research carried out includes linking socio-cultural, socio-economic characteristics of the local community with the resurgence of the disease in the area. Different pesticides and insecticides were recommended and have been used in order to fight against rodents and fleas, which are the main plague host and transfer agents to human beings, but disease continues to persist. The impact of the ecosystem management practices on the resurgence of the plague disease is not well studied as we have no idea about the effect of land use and cover change on the resurgence of the disease, the effect of soil conservation and management initiatives on rodent harbourage is also not known and also the local people's perception of land use pattern/ cover change and the linkages to human plague resurgence in the area has never been documented. This case study aims at harnessing local knowledge on ecosystem

management practices and human plague problems in West Usambaras, Tanzania. As explained by Ellen *et al.,* (2000), "Local and indigenous knowledge" is specific to a place; orally transmitted or demonstrated; "the consequence of practical engagement in everyday life and is constantly reinforced by experience, trial and error, and deliberate experiment"; empirically derived; dynamic; shared but asymmetrically distributed within a population; and holistic and integrative within broader cultural traditions. According to ICSU (2002), for many sustainable development problems at the local level, effective interaction between science and local and indigenous culture is crucial in order to find viable solutions. It has also been stated in the declaration on science and the use of scientific knowledge from the UNESCO-ICSU World Conference on Science that traditional and local knowledge systems as dynamic expressions of perceiving and understanding the world can make and historically have made a valuable contribution to science and technology and that there is a need to preserve this cultural heritage and empirical knowledge (ICSU 2002). Therefore, from the local knowledge in the area, this study shows how local people link the anthropogenic modifications of the ecosystems with the frequent outbreak of human plague in West Usambaras, Tanzania.

1.2 Location, demography and geography of the study area

The study was carried out in eight selected villages in Lushoto district, West Usambaras, northeastern Tanzania. The district lies between 38° 10' and 38° 36' E and 4° 24' and 5 ° 00' S (Fig.2), with altitude ranging from 800 to 2300 m a.s.l. (Kerkhof, 1990). Its population is estimated to be 419,970 people of whom 46% and 54% are males and females respectively (TBS. 2003).

Rainfall is bimodal in pattern; short rains are in October to December with a dry spell from January to February. Long rains fall from March to June with peaks in April. The rainfall ranges from 600 mm in some of the lowlands and rain shadow area to more than 1200 mm elsewhere (Monela *et al*., 1999). The mean annual temperatures vary with altitude, that is at 800 metres above sea level (m.a.s.l) it is in the 25 to 27 °C range, while on the plateau, at 1500 to 1800 m.a.s.l, the range is 17 to 18 °C (Shelukindo 2000).

The soils are generally latosols. However, in the lower wetter areas; soils are humic ferralitic whereas in the drier, cooler areas soils are humic ferrisols (FAO/UNESCO,1979 in Kaoneka, 1993). Their colour is red to yellowish red, but the topsoil is darker. They have high clay and sand contents but are low in silt and freely drained. The pH under forest, varies between 3 and 5, but is higher under crops (Wiersum *et al*.., 1985).

Natural vegetation is comprised of *Juniperus procera, Ocotea usambarensis, Podocarpus* spp*, Albizia* spp, *Parinari excelsa, Pygeum africanum, Syzygium guineense, Ficalhoa laurifolia, Polycias* spp, *Macaranga kilimandscharica,*

Chrysophylum spp, *Olea hochstetteri* and *Cassipourea* spp. In general the area falls under the montane rainforest vegetation type (Kaoneka, 1993).

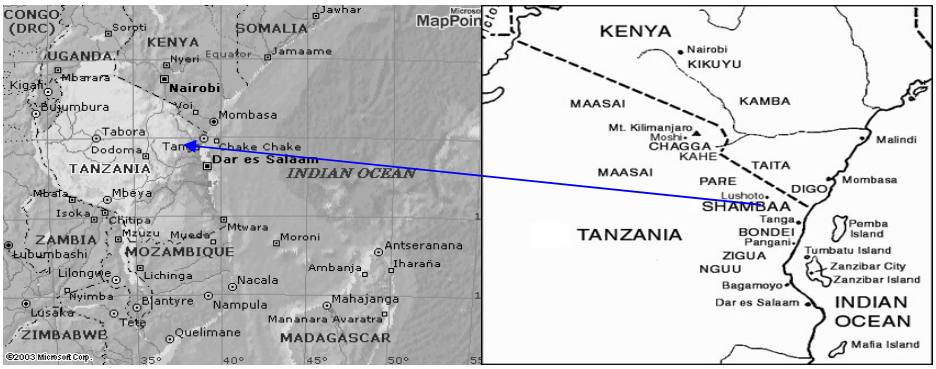

Fig.2 Map showing the location of West Usambaras, Tanzania

1.3 Distribution of the human plague worldwide

The natural foci of plague are situated throughout a broad belt in the tropical and subtropical latitudes and the warmer parts of the temperate latitudes around the globe (Fig 3).

Plague foci are dynamic, changing in response to shifts in factors such as climate, landscape, and rodent population migration. Natural foci of plague persistent at the present time are in North and South America, Africa, Asia, and to some extent, in South-East Europe (WHO, 1999).

According to WHO (1999), in Asia human plague was reported from seven countries (China, India, Kazakhstan, Lao Peoples Democratic Republic, Mongolia,

Myanmar and Vietnam), with a total of 6,501 cases and 374 deaths from 1980 to 1997. Myanmar and Vietnam had 78.5% of the total cases reported in Asia during this period.

In America, human plague was reported from five countries during this period: from Bolivia, Brazil, Ecuador, Peru and the United States. Three of these countries namely Bolivia, Peru and the United States, notified the disease in humans nearly every year. From this continent between 1980 and 1997, the reported cases were 3,137 with 194 deaths (10.8% and 8.3% of the world total respectively).

In Africa within roughly the same period, human plague was reported from 12 countries (Angola, Botswana, DRC, Kenya, Libya, Madagascar, Malawi, Mozambique, South Africa, United Republic of Tanzania (URT), Zambia and Zimbabwe), with a total of 19,349 cases and 1,781 deaths (66.8% and 75.8% of the world total respectively) (WHO, 1999). From these countries, 62.5% of plague cases of the total African reported cases were from Madagascar and URT.

In Tanzania, from 1987 – 2001, human plague was recorded every year totalling 6,233 cases and 402 deaths. The increased incidence of the human plague was due to continuous outbreaks in West Usambaras, which are the current active focus in the country.

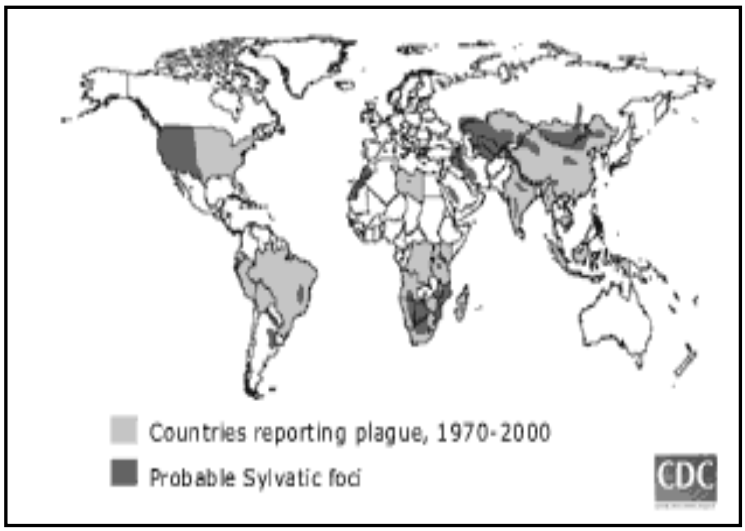

Figure 3. Global Plague Distribution as indicated by Centre for Disease Control

2.0 Case study development

2.1 The approach

Ecosystem restoration in Tanzania, especially in West Usambaras, has been carried out using different approaches. The Government, District Council and some conservation projects including the Soil Erosion Control and Agroforestry Project (SECAP) and the Traditional Irrigation Project (TIP), in Lushoto, have put substantial efforts in an endeavour to restore the degraded areas. Different ecosystem management practices have been carried out in the district in order to restore the lost vegetation cover. Practices such as agroforestry, afforestation as well as improvement of the natural canals in different villages in the district have been undertaken (Shelukindo, 2000). Regarding the plague problem, substantial information on the epidemiology of plague, rodent reservoirs, carnivorous carriers and flea vectors in the district is well documented. Furthermore, studies on the ecology and biology of rodents in stable and

unstable ecosystems and their effects on plague epizootics and epidemics are being carried out (Kilonzo *et al.,* 2003). Additionally, studies on the cultures of people in West Usambaras in relation to plague infection in the area have also been carried out and revealed that socio-cultural, socio-economical, environmental and ecological factors are mostly responsible for the long persistence and repeated outbreak of plague in the district (Kilonzo, *et al.,* 2003). However, the local knowledge on the impact of ecosystem management practices on rodent harbourage, consequent outbreaks of the plague disease and the socio-economic importance of such practices and their linkages to the outbreak of human plague disease were not well covered. Therefore this case study uncovers local knowledge on ecosystem management and human plague problem in this area.

Using a case study protocol developed by the Initiative on Science and Technology for Sustainability (ISTS), the case study has been expanded to look at issues such as stakeholder involvement, the science policy interface and the challenges of interdisciplinary research for sustainable development

2.2 Defining the case study using Initiative on Science and Technology for Sustainability (ISTS) protocol

The international Initiative on Science and Technology for Sustainability seeks to enhance the contribution of the knowledge to environmentally sustainable human development around the world. The Initiative of Science and Technology for Sustainability (ISTS), supports the recommendations by Annan (2000) that one of the

major challenges facing humanity is fostering equitable and sustainable human development while maintaining and nurturing ecological life-support systems, and tries to find the way how this can be attained. Over the past three decades, from the UN Conference on the Human Environment in Stockholm (1972), to the publication of the Brundtland Commission's report *Our Common Future* (1987), to the UN Conference on Environment and Development in Rio (1992), and to the UN World Summit on Sustainable Development (WSSD) in Johannesburg (2002), it is possible to identify a shift in how this sustainability challenge has been defined, framed and addressed: from awareness raising/problem identification to operationalizing or implementing a sustainable development agenda; from the involvement of state actors to the involvement of multiple actors (state, private sector, NGOs, subnational governments) across multiple scales (local to global); and from sectoral issues (water, energy, health) to multi-dimensional, complex systems of interrelated issues (Cash and Timmer, 2003).

This shift has been accompanied by the recognition of the critical role that science and technology can play in addressing the sustainability challenge. Emerging from the WSSD was a broad agreement on the centrality of science and technology (S&T) in understanding and addressing the range of interacting social and environmental issues (Cash and Timmer, 2003). ISTS has developed a research protocol for sustainability case studies to be tested in order to harness science and technology for sustainability. The development of this case study following the developed research protocol, addresses the origin of the idea for conducting this study, who and where are the different stakeholders involved in the development of the knowledge, the contribution of these stakeholders in the development of this case study, how the

decision makers were involved in the development and utilization of the developed knowledge, how the knowledge can be transferred or rather communicated back to different stakeholders at different levels and finally what are the lessons learned and challenges from conducting this study.

2.2.1 The origin of the idea

The research on local knowledge on ecosystem management practices and human plague problems in West Usambaras Tanzania employs a transdisplinary approach, whereby the ecologist has engaged in research that aims at solving human health problems using ecosystemic approaches.

The basic idea of conducting this case study was developed after reading different research findings, including those from biometricians and social scientists including anthropologists, who reported several factors to be associated with the resurgence and persistence of the plague disease in West Usambaras, Tanzania. Most of the findings from different researchers found that socio-cultural, socio-economic, environmental, and ecological factors were mostly responsible for the continuous outbreak of the human plague in the area. From these findings, the author came to the conclusion that ecosystem management practices could be contributing to the resurgence and persistence of the human plague disease in the area and hence more research should be directed to this area. Contemporary issues given priority by the International Development Research Center (IDRC) through its Ecohealth Program Initiative also supported the origin of this area of research. Therefore apart from the author's own initiative, this study is also a product of the IDRC initiative on solving human health problems using an ecosystem approach to human health.

2.2.2 Main actors in the case study

The study involved different actors that are linked in seeking the solutions to the human plague problems in West Usambaras, Tanzania. The stakeholders involved in the development of the knowledge on ecosystem management practices and human plague problems in the area were at two major levels, these are the international level which include the financial communities and the national level subdivided into R&D centres and the local communities (Fig 3)

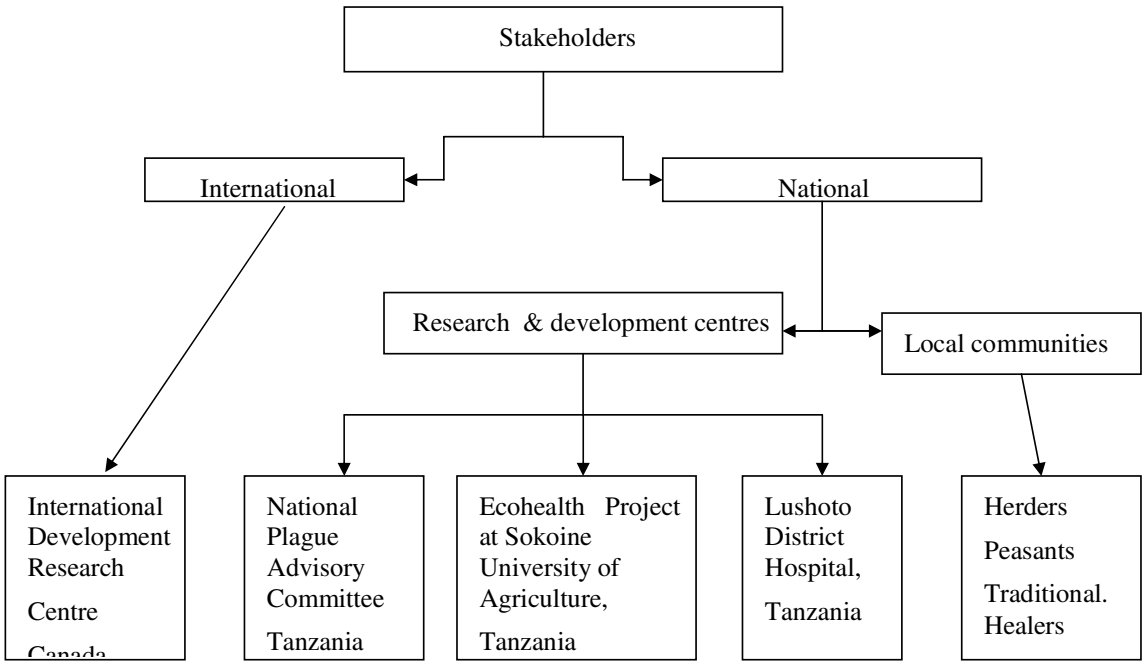

Fig 3. Main stakeholders in the case study development

2.2.3 Contribution and linkages of the actors (stakeholders)

As the case study itself is approached in a transdisciplinary way, the author has managed to involve most of these stakeholders at some stages in addressing this problem. As explained previously the stakeholders involved in this case were at major two levels, national and international levels.

2.2.3.1 Local communities

Local communities were the key and main actors in the developing of knowledge on the linkages between ecosystem management practices and human plague problems in the area. They were highly involved in different phases of the research. In the research area, local communities involved were the herders, peasants and traditional healers, aiming at soliciting different knowledge and views from different groups and representatives. The study also was gender sensitive as males and females were involved in different dialogue meetings held in the area. As explained by Chambers (1983) and Bosch *et al.,*(1996), local communities are better able to discover information about the condition and interrelationships as they have place–based empirical knowledge. Thus, the researcher spent more time working with and looking to the insights of these main actors in the development of this case study. Kasemir *et al.,* (2003) mentioned that, as the public understands and defines the issue then it becomes a complementary input to the scientific assessment and ultimately the policy-making process. The author therefore thought that involving local community as a part of public participation in developing this case study is essential and desirable.

Local communities were involved in defining the research issue using interviews and participatory rural appraisal methods, such as resource mapping, Venn diagramming, problem ranking preference as well as the seasonal calendar. Focus group discussions were also carried out. Kasemir *et al.,* (2003) pointed out that the term *focus group* derives its root from a combination of two standard social scientific research methods, first as a focused interview in which an interviewer elicits information on the topic without the use of a fixed questionnaire guide and the second has been referred to as a group discussion in which a heterogeneous, but carefully selected, group of people responds to a series of particular questions raised by skilled moderators. In this case study both criteria were considered in the focus group method of data collection. Through these methods, a number of ecosystem management practices in the area were identified. These include: tree planting, banana planting, planting of fodder grasses such as Guatemala grass (*Tripsucum laxum*), and elephant grass (*Penisetum purpureum*), sugar cane, practising zero grazing, terracing as well as slash and burn of the vegetation. Local communities suggested that they carry out these ecosystem management practices for their socio-economic welfare (i.e. food, income etc) as well as the ecosystem services such as soil erosion control, obtaining manure from livestock, as well as nutrient re-cycling.

Regarding the impact of different ecosystem management practices on rodent harbourage, which was linked with the frequent outbreak of the plague disease in the area, Guatemala grass (*Tripsucum laxum*) was ranked the first since it is green throughout the year (i.e. both wet and dry seasons), which provides the rodents with good shelter and food through out the year. The second ranked management practice was the improper forest management and forest degradation. Local communities

associated forest degradation with the wild rodent habitat degradation, which has created the centripetal movement of the wild rodents from the wild to human settlements and their surroundings. Leaving farms under fallow was ranked the third practice to be associated with the high level of rodent harbourage and facilitating wild rodents–human contacts in the area. Therefore, the local community in the area acknowledged the anthropogenic modifications of the ecosystems and natural environment to have contributed to the frequent outbreaks and persistence of human plague in West Usambaras, Tanzania.

2.2.3.2 Research and Development centres

Research and development centres were also involved in the development of this case study as stakeholders. The research and development centre most involved was the Ecosystem Health Project on Plague (Tanzania), which is located at Sokoine University of Agriculture, dealing with the human plague problems in West Usambaras. Other stakeholders from this group included the Lushoto Distinct Hospital, whose officials have assisted the researcher in working for the research permits to the villages and located the villages that were frequently affected by the human plague problem in the area. The district medical office has a good data base in which villages report the resurgence and frequent outbreak of the disease in the district, how many cases are reported each year, including both fatal and suspected cases and what they have been doing to prevent the frequent outbreak of the disease. Thus, in one way or another the district hospital has been useful and is a potentially important actor in the development of the case study. In this group all stakeholders have a similar interest in trying to reduce human plague vulnerability in West Usambaras, Tanzania.

In the case of the National Plague Advisory Committee, another of the case study stakeholders, there was no direct link with the researcher but as most of the members from Ecosystem Health Project on Plague and the district hospital are members of this committee, the committee has been indirectly involved in the development of this case study.

2.2.3.3 International organizations

At the international level, the International Development Research Centre (IDRC) of Canada, under its Ecosystem Approaches to Human Health Program Initiative, facilitated this case study by providing research funds. This illustrates a typical example of the importance of the international financial communities in developing science and technology for sustainability. In particular they are important because they develop a type of science that applies a transdisciplinary approach to solving human problems, some of which have been a result of the chronic long-term impact of climate change. There is a need for the international funding organizations to recognize the importance of capacity building in sustainability science, since there is an urgent need for more scientists that can be involved in conducting research that links with different policy makers in order to achieve the often cited goals of sustainable development. The effort to address sustainable development issues or to increase scientific capacity should take place in a context of very different patterns, environmental concerns, and research orientation (Clark *et al.,* 2002). From the example of IDRC as one of the financial communities in developing science and technology for sustainability, more international financial communities should develop education, training and technological services that build capacity at the individual, national and regional levels, in order to strengthen

and stimulate innovation activities that if properly communicated to the policy makers could contribute effectively to sustainable development and improve human quality of life without compromising lives of future generations.

2.2.4 Communication of the research findings

The communications of the research findings is being carried out in various ways at local, national and international levels. At the national level, the communication of the results is being done in different ways including, the feedback with the local communities during the PRA dialogue meetings that were conducted in the area and the report that has been submitted as a partial fulfilment of the requirement of for the degree of master of science at Sokoine University of Agriculture. Moreover the author is trying hard to have an audience with the National Plague Advisory Committee in order to present the research findings from this case study.

Regarding the communication of the results or research findings at the international level, the researcher has submitted a technical research report to the financial sponsor (IDRC), two papers have been presented in two international conferences held in two different countries which were attended by different scientists as well as policy makers from several countries. A summary of the research findings will be developed in *Kiswahili* language, the language of communication in Tanzania, and will be distributed to the respective national stakeholders as policy briefs, these will include villages where the study has been conducted as well as at the district level. Therefore, regarding the communication of the research findings much has been done at

the international level compared to what has been done at the national level. There has been less consideration of reporting the findings at the national level where the actual problem persists compared to what has been done at the international level. This is a typical pattern for many research results in different areas in the world, where more attention is being given to the communications that are done at the international level. Therefore, the ISTS proposed protocol is more useful and appropriate as it reminds researchers to communicate the research findings at local, national and international levels.

3.0 Lessons learned and challenges

3.1 Lessons learned

Different lessons have been drawn from this case study at the local to the international levels.

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Local communities in the area linked the anthropogenic modifications of the ecosystems and natural environment with the frequent outbreaks and persistence of human plague in West Usambaras, Tanzania. They suggested that forest degradation creates the centripetal movement of the wild rodents from the wild to human settlements and hence is a causal factor for the resurgence of human plague in the area.

In order to harness useful science and technology for sustainable development , different stakeholders should be involved in the process as each stakeholder/actor has a role to play in contributing to the solutions of sustainability problems.

As one of the stakeholders, media was forgotten in the development of this case study, and has been observed to be one of the very important actors in communication of research findings, thus in order for the information flow to be achieved media should also be included as one of the stakeholders in the development of similar case studies in the West Usambaras or elsewhere in the world.

In most of the research findings, it has been found that communication is geared to the international levels, feedbacks to the local communities is very minimal, thus, from ISTS protocol we are learning that researchers should focus on developing a proper way for disseminating the research findings equally at local, national, regional as well as international levels.

Local Research and Development centres are useful and important for the development of science and technology for sustainable development as they are the source of expertise and skills in developing the proper area-based methodologies and because most of the local experts can speak the same language with the community in question.

The use of the proper language to the local communities is very important ,as from several discussions held it has been learned that more credible issues to local communities are conclusions from other stakeholders, which need to be translated using a proper and understandable language to them.

The use of participatory approaches in applying ecosystem approaches to human health can add value to the efforts of solving human health problems, as it stimulates local communities' understanding of the linkages existing between environmental changes and the impacts of those changes on their well-being.

International financial communities are very important in facilitating the development of the sustainability science because of the costs of developing the science and technology. Therefore the financial communities should be willing to participate as stakeholders in the development of the sustainability science.

3.2 Challenges

Through extending this case study by applying the ISTS protocol, several challenges arose, including:

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The need to understand and quantify the anthropogenic modifications of ecosystems and their related impacts on people in the area (i.e. understanding the coupled human-environment system).

The need to develop scenarios that will assist in projecting the impacts of the environmental changes on human health in the area.

The importance of assessing the linkages between exposure, sensitivity and resilience components of the human plague vulnerability in West Usambaras as a basis to build recommendations on how to reduce plague vulnerability in the area.

It is essential but also very challenging to ensure that the science and technology we are producing is credible, salient and legitimate to both local people and policy makers in order to favour the application of science and technology for sustainable development.

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