G-1.3 Comparative Study of Human Activities on Desertification in Arid and Semi-arid Areas of Different Countries

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Abstract We conducted field investigation in India, China, Thailand, Kazakhstan in Asia, and also in some African countries, to compare and understand the desertification processes. We made a comparison concerning human activities and desertification by "minimum dataset" approach with regard to climate, soil and water, vegetation, land-use and socio-economic variables.

Key Words Desertification, International comparison, Minimum dataset, India, China

1. Introduction

UNEP defines desertification as land degradation in arid, semi-arid and dry sub-humid areas resulting from adverse human impact. Here, land degradation implies reduction of land resource potential through soil erosion (wind and water erosion), salinization and decrease in production rate and biodiversity. However, land degradation occurs not only in these areas but also in other bioclimatic zones. For example, severe salinization problem can be observed in irrigated hyper-arid areas and, on the other hand, in cultivated wetlands in the humid tropics. Wide range of observation of desertification/land degradation phenomena is kept for establishing the method of combating desertification.

Asian Continent is characterized as a region with vast amount of desertified drylands. UNEP/GRID reported in 1991 that Asia contains nearly 2 billion ha or 32% of the world dry lands, which is almost same amount reported in Africa. More than 70% of Asian dry lands are exposed to the threat of desertification. In addition, land degradation is significantly recognized in hyper-arid areas in Central Asia and in humid sub-tropics and tropics in East and Southeast Asia. It is quite obvious that the amount of irrigated lands is very high and ratio of desertified lands in irrigated lands is also high in Asia, which suggests one of the characteristics of desertification in Asia. Understanding of desertification in Asian context will highlight common and unique characteristics necessary for promoting world-wide comparative desertification studies.

2. Methods

We selected four countries, India, China, Thailand and Kazakhstan from Asia (TABLE 1) and some countries from Africa to compare desertification processes in Asia and Africa. For the analysis of climatic conditions of study areas, we used 'Global Historical Climate Network' (GHCN) datasets and made climate diagrams (FIG 1).

3. Outline of desertification in study areas

(1) India

TABLE 1 Study areas and desertification processes

Area (Country)	Bioclimatic zone	Dominant landuse	Land degradation
Jaisalmer (India)	Hyper-arid	Nomad	Salinization by irrigation
Xinjiang (China)			
Jodhpur (India)	Arid	Nomad, Pasturage	Grassland degradation by overgrazing, Wind erosion
R. Ili basin (Kazakhstan)			
Neimenggu (China)	Semi-arid	Pasturage	Vegetation degradation, Wind & Water erosion
Nyngxi (China)	Dry sub-humid	Rainfed cropping	Water erosion, Forest degradation
Khon Kaen (Thailand)	Humid	Cropping, Forestry	Deforestation, Water erosion
Zhejiang (China)			

1) Water and wind erosion

The concept of potential erosion helped much in understanding the spatial distribution pattern of the erosion through water and wind. Following the Universal Soil Loss Equation (USLE), The rainfall erosion index along the eastern margin of the arid lands in India has been calculated as 300. It has not yet been successfully applied to the arid areas. There are other methods of calculating the potential water erosion also, but the search for a realistic index is still continuing. However, the pattern of water erosion could be deciphered from the sheet, rill and gully erosional features. These features are numerous along the eastern margin of the desert where the average annual rainfall varies from 350 to 500 mm, but are very few to the west of the 250 mm isohyet.

The most vulnerable landforms are the sandy lands near the Aravalli ranges, the medium to heavy textured alluvial plains and the sloping uplands and colluvial plains in between the Aravalli ranges. Although increased ploughing of the land and destruction of vegetation cover must have accelerated the erosion, it is yet to be established as to how much of it is due to human activities and how much is natural under the environmental set up of the region. The accelerated water erosion in the arid Kachchh and Saurashtra is mostly due to neotectonism. Human activities are aiding the process, especially in the areas of shallow soils where the impact is felt much faster and in a more glaring fashion.

2) Salinization and alkalization

Accelerated salinity-alkalinity hazard is dominant in the medium to heavy textured alluvial plains, especially because of irrigation with saline ground water. In the seaward margin of the coastal alluvial plain very high pumping of potable ground water has led to an intrusion of saline sea water into the aquifer. Since the farmers have no other choice as regards watering of the crops, they continue to use the ground water even after its quality has been adversely affected by sea water intrusion. In the Indira Gandhi Canal command area in the Thar, the problems of water logging and salinity-alkalinity are increasing at a faster pace. This is mainly because the soil is followed at a shallow depth by a barrier of gypsum or calcium-rich formation. Profuse irrigation in such a terrain has led to waterlogging and subsequent salinity of soil. Such salinity build up has also been noticed in the command areas of small irrigation tanks in the south-central part of the desert and where the canals have crossed some salt-rich palaeochannels.

(2) China

1) Salinization caused by irrigation in hyper-arid areas in Xinjiang Uygur

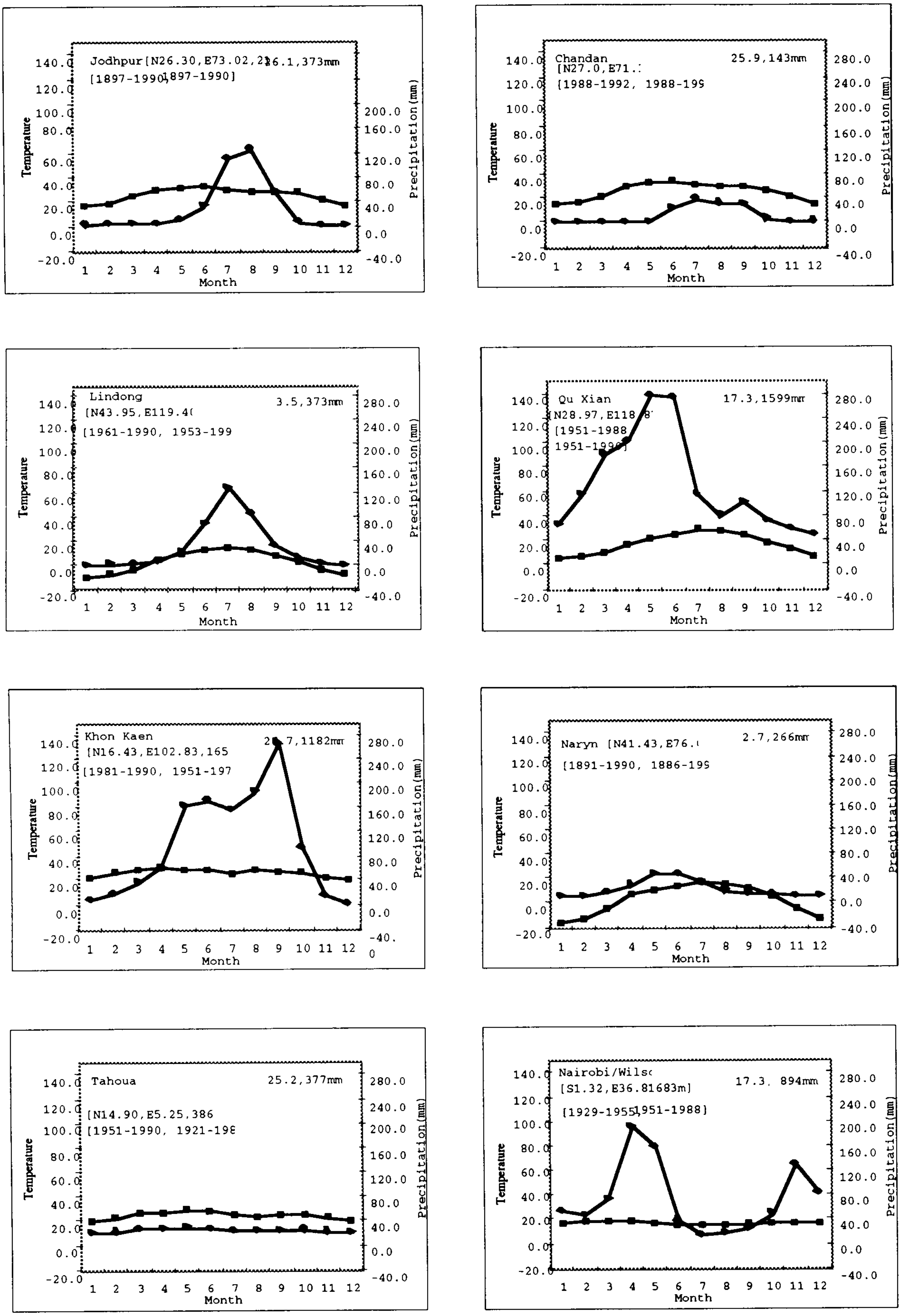

FIG 1 Climate diagrams

Severe salinization is observed in Fukang area, located at the northern foot slopes of Tianshan Mountains. Here arable lands with irrigation system was reclaimed in the 1960's by military settlers using melt water coming from glacier at the top of Bogda Mountain. At present, wheat, cotton, rice and capsicum are major products. However, because of the advance of severe salinization caused by irrigating hyper-arid environment, abandoned lands have expanded. Comparison of satellite image in 1977 and aerial photo in 1987 shows that 61% of arable lands are abandoned, mainly by the salinization of grassland soils. Institute of Biology, Soil Science and Desert Research, Chinese Academy of Science is trying to improve degraded lands by introducing salt-tolerant crops and improving irrigation system by saving water and constructing underground canals.

2) Sand dune remobilization caused by deforestation and over-grazing in semi-arid areas in Inner Mongolia (Neimenggu)

Grasslands with patched distribution of forests dominated by *Pinus-Quercus* and *Ulmus* woodlands have degraded through human impacts in Wulan-Aodu area, Inner Mongolia. During the time of "Great Leap Forward" for promoting iron melting announced in 1976 by the communist leader and the construction period of large reservoir in this area, trees were cut intensively for firewood, resulting in destroying forests and woodlands and induced accelerated sand dune remobilization. Gradual increase in population both people and domestic animals has also affected on the land degradation. Over-grazing has brought rapid decrease of grassland biomass. Digging of salinized lowland soils for housing materials has brought the irreversible change in soil potential . Institute of Applied Ecology, Chinese Academy of Sciences is trying to rehabilitate desertified landscape by improving grasslands and planting trees to stabilize sand dunes.

3) Water erosion caused by deforestation in humid areas in Zhejiang

Lanxi area, Zhejiang is geomorphologically characterized by the hills and lowlands. Before the World War II, weathered surface of the hills were stabilized by covering of *Pinus* woodlands and paddy fields were well developed on lowlands. Here, "Great Leap Forward" brought strong impact on wood lands, resulting in decrease of logging and increase of denuded hill surface. As a result, accelerated soil erosion was occurred in the humid environment and the landscape called 'red-colored desert' (degraded landscape of sub-tropic acid red soils) was appeared. Eroded soils were accumulated on lowland, which made lowland farming difficult. Increasing demand of firewood has caused soil erosion, too. Local government and farmers started land improvement such as afforestation and rehabilitation of lowland arable lands. At present degraded land s are gradually decreasing. However, in Changshan area, west of Lanxi denudation of hills is still major problem causing flood after heavy rainfall.

(3) Thailand (FIG 2)

In Thailand, forest occupied 53% of the total land area in 1961 and decreased to 28% in 1987. Forest in Northeast Thailand is 12.7% of that region, which is far less than the average. Two types of soil degradation are encountered, i.e. soil erosion on hilly lands and salinization in the depression. According to Department of Land Development, almost 90% of Northeast Thailand are more or less subjected to soil erosion and about 30% of them is moderately eroded soils. Mitsuchi et al. (1986) and Miura et al. (1990) reported that 17% of the lowlands are salt-affected soils.

Northeast Thailand receives about 900 mm per annum and has potential evapotranspiration of 1800mm, thus, the climate of this region is sub-humid. Precipitation is concentrated in two rainy seasons (May through June and September) and dry season in November through February is quite severe. Thai farmers have traditionally been working for lowland rice cultivation in the valley bottoms and/or flood plains and, thus, uplands under forest vegetation in that region have been used for supplemental crop production.

Due to the population growth of their own and immigrants from mountainous areas in and adjacent to Northeast Thailand, forest, however, has been cleared for the development of upland farms since 1960s. New farmers settled on the hill slopes started upland rice cultivation and moved to cassava and corn after the decline of soil fertility. Soils in this region are mostly sandy and their inherent fertility is very low. Deforestation for the development of upland farm decreases the amount of water evaporated through vegetation, resulting in the increase of surface run-off as well as percolation water through soil bodies. The former induced soil erosion, while the latter contributed to higher water table, which transported salts from soil bodies up to soil surface, in other words, salinization started.

The soils in this region inherently include high percentages of Naco in soil bodies. Major reasons of soil degradation here are population growth, immigration from the surrounding areas, scarcity of farm land for subsistent agriculture, low inherent soil fertility, raise of ground water level and high salt-containing soil material.

(4) Kazakhstan (FIG 3)

In North and Central Asia is distributed 200 million hectares of salt-affected soils under arid and semi-arid climates. The former Soviet Union has developed large scale irrigation scheme for the production of cotton and rice in Central Asia since 1960s. Environmental problems due to irrigation practices for the last three decades in this area have been recently reported, which include the shrinkage of inland lakes, such as Aral Sea and Lake Balkhash. Farms and surroundings are also affected to show salt- accumulation on the soil surfaces. Rozanov (1984) reported 1 million hectares of irrigated land was lost in Central Asia because of erroneous irrigation practices. According to Khakimov (1981), the percentage of moderate to severe salinized soils in that area reached 60 to 70% and crop yield decreased by 30 to 33%. Soil degradation observed in this area is salinization due to irrigation under the dry climates.

This area is characterized with very low precipitation (ca. 150 mm per annum) and cool temperature (9 ℃, average). The original vegetation is semi-desert shrub of *Haloxylon spp.* and land was used for grazing cattle before irrigation schemes were constructed. Population density is very

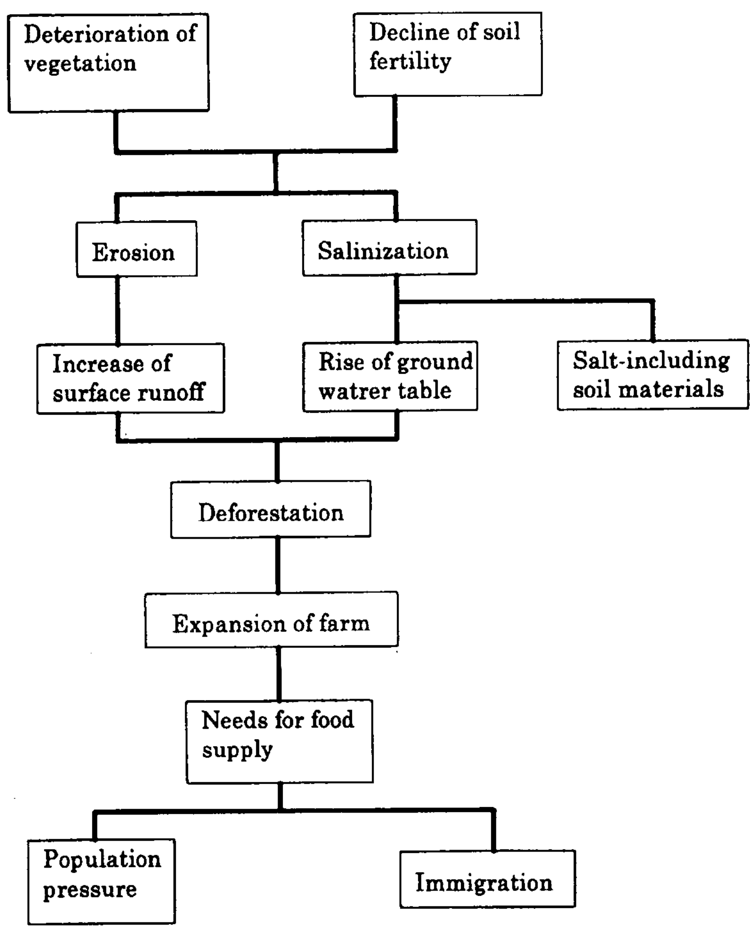

FIG 2 Causes and impacts of desertification of NE Thailand

sparse. Soils are more or less sandy and include calcium carbonates and sulfates in the subsoil.

Most of the desert soils have some salt accumulating layers in the soil bodies. In natural condition, such salt accumulation layers can be observed in the subsoil but not in the surface soils. This is because even a very limited amount of precipitation can dissolve salts in soil bodies and let them move down to some depth from the surface. Thus, ordinary upland does not pose salinity problem. Only in the depression with high water table salts are encountered on the soil surface.

Irrigation, however, changes the water regime of upland soils. Once the farm is irrigated, irrigation water percolates through soil solemn and raise the level of ground water, if drainage is not very much efficient. Where the ground water table is high capillary connects the ground water and the soil surface. Under the arid climates, evaporation rate is very high and the ground water moves upward. Moving up through capillary, the ground water dissolves salts accumulated in the subsoil and transport them to the soil surface, where only water evaporates and the salts are crystallized on the soil surface. High salts contents in the surface soils may disturb the normal growth of plants and destroy vegetation cover if the situation is serious. Soil degradation (salinization) is due to mismanagement in the application of irrigation water.

(5) East Africa (FIG 4)

Rwanda and the eastern part of Zaire are located in the area of Great Rift Valley of East Africa. Most of the area is more than 1,000m above sea level. This region is mountainous and steep topography, although the climate is quite mild. Soils are derived from basaltic lava and very fertile, if compared to those in other parts of Africa. Almost all hill slopes are permanent farms and utilized for staple food production, mainly banana, kidney beans, cassava, sorghum, sweet potatoes and maize. Soil degradation encountered in this region is sheet erosion and the subsequent decline of soil fertility.

As mentioned above, soils are very fertile here, thus, the area is very densely populated since before the independence. Although we do not have detail census data, it is even said that the population density in this region is over 800 persons/km^2, and the population is still rapidly increasing. Jurion and Henry (1969) reported that the farms were originally rotated with long fallow (about 20 years). They are now, however, split into small pieces and continuously cultivated. Some farms may have a short fallow period (2 to 3 years). The farmers tend to open new farms on steep hill slopes and/or swamps which have not yet fully utilized before.

The area has quite high rainfall (ca. 1,400mm per annum) with cool temperature (17 to 19℃). Although natural vegetation was forest, some part of it was cleared for the cultivation of cinichona and chrysanthemum as exporting

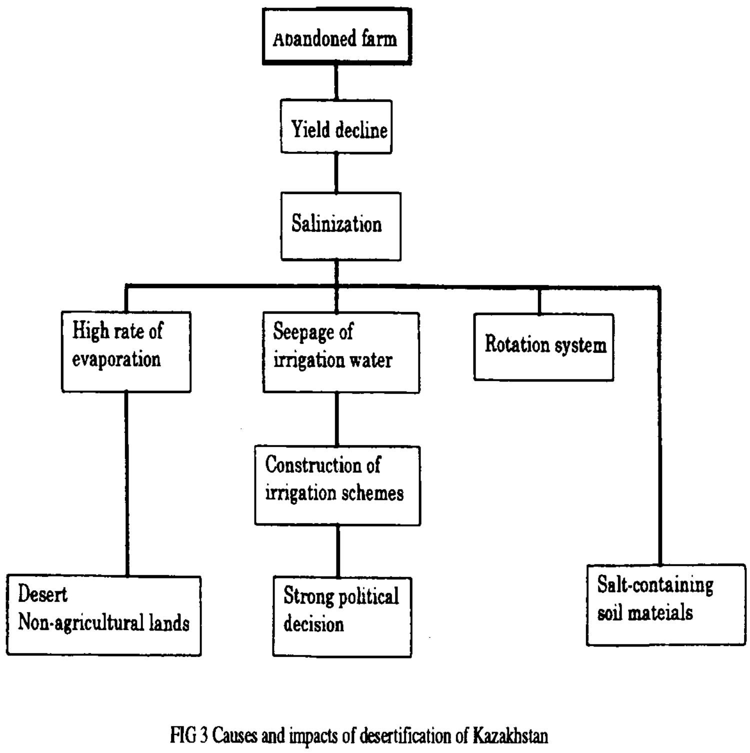

FIG 3 Causes and impacts of desertification of Kazakhstan

cash crops at the time of Belgian occupation. Such plantation farms were managed with contour cropping with rows of elephant grass against soil erosion on the steep slopes. They were, however, reformed into the farm for staple food crops after the independence and some rows were removed, where we now observe serious erosion problem. Major reasons of soil degradation here are high population pressure, scarcity of farm land for subsistent agriculture, high rainfall, steep topography and mismanagement of farms in terms of erosion control.

Erosion induces the loss of not only fine soil particles but nutrient cations and organic matter, causing deterioration of soil fertility as well. Deforestation for the development of new farms to feed the increasing population may accelerate soil erosion with the increase of surface runoff. Swamps and lowland shall be utilized more intensely and we must develop an appropriate technology for efficient utilization of lowland, since no one have yet taken serious consideration on lowland in this region.

Although the farm on the hill slopes are subjected to serious erosion, hill tops near housing compound have been carefully managed against soil erosion as well as soil fertility decline. These areas are planted with banana, which is very important cash crop in this region. They produce and sell banana beer, thus, they take very much care of banana farms with applying organic manure made of kitchen waste and animal dung and mulching with weed grasses and banana leaves. Kitchen gardens planted to vegetables are also managed in a same manner in terms of erosion and fertility control. These farms are very rich in nutrient status with favorable soil physical condition. Hence, we recommend to reallocate of farm plots for erosion and fertility control, so that banana grove be on the slopes and farm for food crop be on the hill tops, because banana grove is very efficient for protecting eroded soil materials. Contour belt with banana grove on sloping farm may also contribute to the protection of nutrient losses in soil solutions as well as mass movement (Kosaki and Kyuma., 1989).

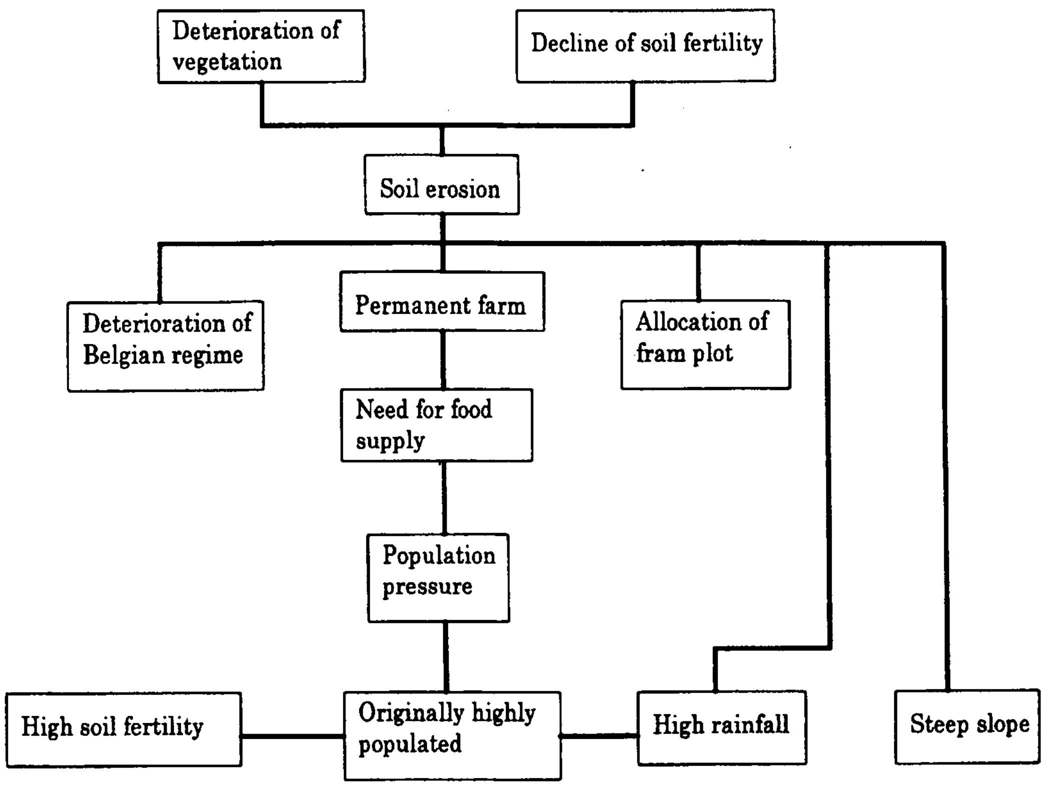

FIG 4 Causes and impacts of desertification of East Africa

4. Conclusions

1) All examples of desertification investigated by the study are induced by human activities, mismanagement of land-use. Therefore, desertification processes are strongly related to the land-use systems. The most typical land-use in dry lands are livestock farming and cropping. In pastoral land, overgrazing is the biggest factor of desertification (e.g. Inner Mongolia, China). On the other hand, cropping land consists of irrigated and rainfed agricultural land. In the former (e.g. Kazakhstan), salinization, in the latter (e.g. India), water and wind erosion is a causal factor of desertification.

2) The desertification processes are related to races through land-use system. In China, the Mongolian and the Chinese are living nearby, but because the land-use system is different between two races, the desertification process is also different.

3) The change of land-use system caused by the movement of a race may cause desertification. In Thailand, the invasion of low land people to uplands caused the destruction of traditional, sustainable land-use system.

4) Population increase is an indirect factor of desertification. In Inner Mongolia, the increase of human population led to the increase of livestock population, resulting in overgrazing.

5) Some cases of desertification/land degradation were caused by the central and/or local governmental policies.

6) It is important to reexamine the significance of the traditional land-use system, originally practiced by a native for long time.

5. Publications

Towards solving the global desertification problem (1) - Feasibility study on the environmental assessment of desertification in arid and semi-arid areas (in Japanese), NIES, F-37-'92, pp. 97, 1992.

Towards solving the global desertification problem (2) - Research on the evaluation of interaction between desertification and human activities (Edited by T. Miyazaki and A. Tsunekawa), NIES, F-69-'94, pp.91, 1994.

Towards solving the global desertification problem (3) - Desertification Bibliography Database (Edited by T. Miyazaki and A. Tsunekawa), NIES, F-74-'95, pp. 227, 1995.