A Proposal on Arid Land Sabo Works
- a case study in Jordan -

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Abstract

Arid land is defined by Dry-index and Precipitation depth (UNEP), and Arid land amounts to the 40% of terrestrial parts of the world. Nowadays sediment-related disasters by sediment movement such as Debris flow, Sediment flow and so on, occur in Arid land. For example, intense rainfall events results in Sediment flow that causes miserable damages to human lives, houses, agricultural land and infrastructure facilities in Jordan.

From now, intense rainfall may occur more frequently by climate change, and development area may be sprawling by increase of population on the dangerous alluvial fan in Jordan. Therefore sediment-related disasters may increase in Arid land in future. So it needs the development of the Arid Land Sabo Works that means not only to prevent the sediment-related disasters but also to use the water of surface flow or flowing water. To make the safety in the Arid land of the world, I propose Arid Land Sabo Works with due regard to the characteristics of Arid land.

Key words: Arid Land Sabo Works, Arid land, Sediment-related disasters, Re-use of the water

1. Introduction

Recently unusual weather has been causing disasters in different parts of the world. Arid regions such as the Middle East and North Africa in particular are experiencing torrential rainfall in a short period of time, this leads to the occurrence of flash floods which in turn cause damage.

On the other hand, people in these regions have historically developed their lifestyle in an environment which has little rainfall and people consider rainfall as something precious. However, in their traditional nomadic lifestyle, they had a low possibility of being hit by disasters caused by rainfall. Therefore, people in these regions have a different attitude towards disasters caused by rainfall from the attitude in Japan. They are also less aware of the concept of disaster prevention.

Furthermore, these regions have been seeing increasing urbanization and the development of permanent settlements in recent years, and so ensuring the safety of these areas is a new issue for the people who live there.

For example, in Jordan (the Hashemite Kingdom of Jordan), damage caused by rainfall is becoming common, this includes the loss of lives, damage to houses, as well as increasing damage to public facilities such as airports and roads.

Based on the information about sediment-related disasters in Jordan, this article proposes Arid Land Sabo Works with the aim of preventing damage by rainfall in Arid lands such as the Middle East, and securing safe areas to live.

2. What is Arid land?

The classification of Arid land is specified in the United Nations Environment Programme (UNEP 1997) (1). According to UNEP, when precipitation depth is P and potential evapo-transpiration is PET, the value calculated as P/PET is called the dry-index. UNEP classifies Arid land by using the values of the dry-index as shown in Table-1.

In this article, Arid land is defined as areas which include “arid,” “semiarid” and “dry-subhumid”, considering of water use, which are classified in Table-1.

It has been understood that the amount of precipitation from one rainfall on Arid lands varies significantly, whereas overall

precipitation amounts quite little.

Classification of arid land	Dry-index (P/PET) value	Percentage of the land on terrestrial parts of the world (%)
Hyper-arid	P/PET < 0.05	7.5
Arid	0.05 < P/PET < 0.2	12.1
Semiarid	0.2 < P/PET < 0.5	17.7
Dry-Subhumid	0.5 < P/PET < 0.65	9.9

Table-1 Classification of Arid land by UNEP

It is known that about 40% of terrestrial parts of the world are Arid land and many problems are occurring there now.

“Desertification” is a word which sounds similar to Arid land. “Desertification” is defined as “land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities” (the UN Convention to Combat Desertification 1994). Therefore, the land where desertification is occurring and the Arid land which is dealt with in this article could overlap, but “desertification” only means the phenomenon of land degradation and is not the synonym for “Arid land.” The term “Arid land” in this article indicates arid areas including the areas where “desertification” (land degradation) is occurring.

3. The Necessity for the Arid Land Sabo Works

Arid land was not created overnight. The Arid lands of today were created by a long-term process of climate change, accompanying some destruction of the natural environment caused by human activities. Water has been valuable for those who live in Arid lands and rain has been considered a blessing because it provides them with precious water. Consequently, they think of rain differently from the Japanese, because they regard rain as a blessing rather than the cause of disasters.

Then it is probable that the people and their ancestors, who have had such ideas above for the past 1000 to 2000 years, have not regarded wadis (which do not always have water flow) as a river and considered floods as something escapable.

However, in recent years, development has started in these areas due to the population increase, and disasters which need preventive measures are to occur as a result of the development. A particular concern is that houses, agricultural land, and major infrastructures such as roads have been developed on alluvial fans which were created by wadis. There will be more serious damage when the run-off of sediment occurs by a rainfall. In some areas heavier rainfall and disasters may be induced, because of climate change.

Another cause for the disasters increase is due to a change of lifestyle in the Arid lands, where people have started to settle in fixed places and urban populations are growing.

In fact, damage caused by sediment-related disasters is becoming common in Arid lands in many parts of the world. These phenomena are generally called “flash floods” in the world. However, video images of the flood flows and the flood damages in Jordan seem to be those of the run-off of sediment. Therefore, the term “sediment-related disasters” is used in this paper.

Arid Land Sabo Works may become necessary in arid areas of the world in the future. By utilizing the characteristics of Arid land, the Arid Land Sabo Works should provide integrated countermeasures which include preventive work against sediment-related disasters caused by sudden rainfall, the usage of limited amounts of precious rain water, prevention of soil erosion, as well as long-term environmental measures such as afforestation.

4. Sediment-Related Disasters in Arid land – a Case Study in Jordan

4.1 The Natural Conditions and the Social Conditions in Jordan

Jordan neighbors Iraq to the East, Israel and the Palestine to the West, Syria to the North and Saudi Arabia to the South. The Kingdom has 90,000 km^2 of land and is governed by the hereditary king from the Hashemite. Local political jurisdictions are divided into 12 prefectures called Muhafadhah.

4.1.1 Topography and geology

The topography of Jordan is classified into three types as shown in Fig.-1. Desert, or Badia by local name, occupies 80% of the land. Permanent dwelling areas are located on the highlands, ranging from 700 m to 1,500 m, and in the rift valley, known as Jordan Valley, which includes the Dead Sea at 418 m below the sea level. In these areas, Cities and settlements are found.

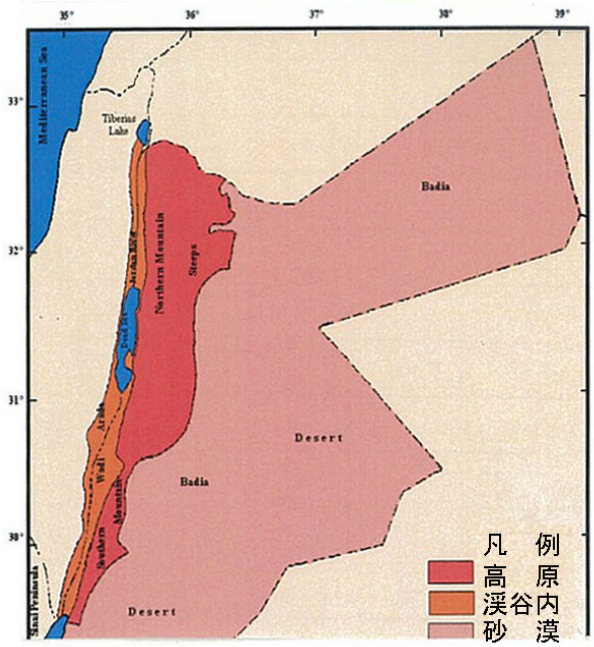

Fig.-1 Topographic feature of Jordan

The highlands in Jordan extend on the eastern side of the Jordan Valley and large cities such as Amman, Karak and Ma'an are built there.

Mt. Umm Al-Dami is the highest mountain in Jordan, the summit of which reaches 1,854 m above sea level and commands the Saudi Arabian border in the south.

The climate inside Jordan Valley is hot in summer but mild in winter and the area has become a major production area for vegetables and fruits grown by modern irrigation. It is said that 70% of vegetables and fruit consumed domestically come from the valley. A part of the produce is exported to Europe via Turkey.

The geology of the country consists mostly of sedimentary rocks; there are mudstone, shale and limestone, originated from the Cretaceous period, and lime-mudstone and chert from the Paleogene period.

The bed of the rift valley is covered by alluvium sediments from the Quaternary period.

Basalt is also found in the desert area to the east and Pre-Cambrian granite widely outcrops in the south including vicinity of Aqaba.

4.1.2 Precipitation

Jordan is one of the countries which have been suffering from the worst water shortage in the world. The National Agenda which was published in 2005 addressed the water sector as the highest priority for infrastructure development. Rain water is an especially important water resource for Jordan but the precipitation is limited. The surface water use is only 40% of the overall use of water resources (2).

The majority of the country receives only 150 mm or less as annual precipitation, although very limited areas have more than 500 mm (Fig.-2)(3). It is said that the average annual precipitation for the whole country is only about 100 mm.

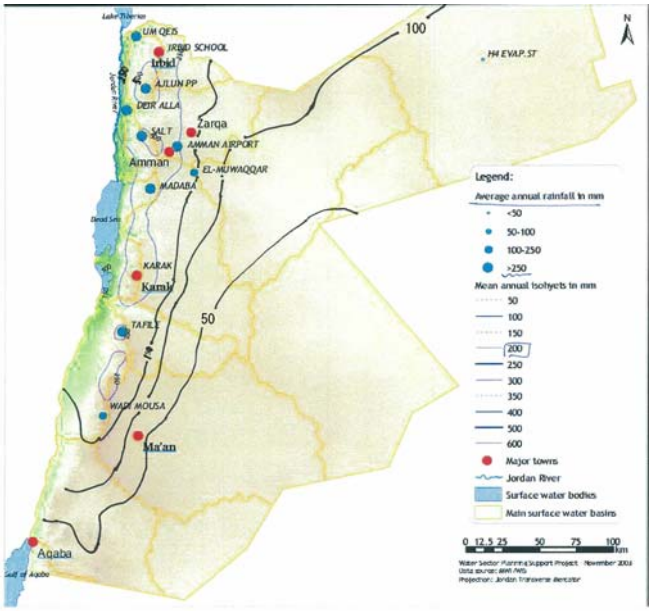

Fig.-2 Average annual rainfall in Jordan

An additional problem to the limited rainfall is that some of this rainfall is lost to run off without use. This loss may be caused by the unique pedological property of the surface material in Jordan. Fine weathering products of montmorillonite origin is blown in and fills the space of the surface gravel like cementation. The gravel rich surface is called "desert pavement" and forms an impermeable layer. It was

explained to the author that these fine material is directly struck into any gaps by the hammering of raindrops.

4.1.3 Vegetation

In the desert area, most part has poor vegetation. Plants are rarely found. On the other hand, much vegetation can be seen on the highlands and inside the rift valley to the north. This is a typical area where water availability influences the vegetation.

4.1.4 Demographic Situation

When looking at the population statistics of Jordan, the population in 2003 was 5.48 million and the annual growth rate was 2.8% (4).

The country may have a contemporary population of about six million, 10% of which are said of recent Iraqi and Palestinian immigrants, etc. The population has started concentrating in the cities, and the urban population ratio has grown from 39.6% in 1952 to 78.7% in 2002. The present urbanization seems to exceed this figure.

4.2 Situation for Sediment-Related Disasters in Jordan

The following is an overview of sediment-related disasters in Jordan, summarized from my field study, as well as based on information from administrative officials and newspapers, etc.

4.2.1 Sediment-Related Disasters inside the Jordan Valley

Inside the Jordan Valley is intensively developed for agriculture, but agricultural production areas are few in Jordan. Transportation of these agricultural products relies on the national road which runs through the valley. Recent sediment-related disasters often cause damages to these agricultural lands and to the national road. In 2006 and 2007, 17 districts north of the Dead Sea have been hit by sediment-related disasters. The Wadi Nhairr area was struck by a disaster on October 27, 2006 which caused damage to the houses and waterways. Agricultural lands and roads were also damaged in Kraima district. One of the causes of the damage is explained by the fact that the river course was diverted in a direction parallel to the road without enough cross sectional area for drainage downstream (Photo-1).

With regard to the areas south of the Dead Sea, basins of seven rivers have been hit by sediment-related disasters. Major damage has been inflicted on roads and also new houses in some places.

Photo-1 Damage of road north of the Dead Sea

4.2.2 Sediment-related Disasters inside the Aqaba Special Economic Zone on the Red Sea Coast

The Aqaba Special Economic Zone is an area where privileges such as tax exemptions and exemptions from import duties have been introduced in order to attract foreign capital. The area is expected to create employment for about 70,000 people over two decades. Construction work is in rapid progress in this area in order to create housing districts and business districts with improved road system. The developments are on alluvial fans of wadis, which do not always have water, so the area will inevitably be hit by disasters when flood happen.

In fact, a container company's yard at the mouth of Wadi Mabrak was struck by a disaster in February 2, 2006, causing a casualty. On the same day, the disaster hit the alluvial fan of Wadi Yutum and caused large scale sediment-related damage which included five deaths, the destruction of 18.5 km of water pipes and water production wells, and damage to the airport (Photo-2). Wadi Yutum is within the main development area in the Aqaba Special Economic Zone.

Photo-2 Development area north of Aqaba city on the alluvial fan of Wadi Yutum (Sediment flow took course in central white part)

4.2.3 Sediment-Related Disasters in Other Areas

Wadi Mujib was resulted from the erosion of the highland in the central part of Jordan. A large amount of sediment which was carried away has created a peninsula sticking out into the Dead Sea. The Mujib dam was constructed in 2003 for supplying water to the Capital Amman, to the south of the Dead Sea for irrigation, to the east coast of the Dead Sea for regional development, as well as to Mujib area for future demand. At a height of 62 m and a total length of 765 m, the dam which was constructed by RCC method has a water storage capacity of 32 million m^3. It was designed in such way that gate operation is not required, letting flood water overflow the levee crown of the dam. The spillway of dam is designed for 5,839 m^3/s of flood water considering safety.

In February 2007, a large scale landslide occurred on the upstream area of this dam. A slope which had some cracks was also observed inside the dammed lake. New landslides may occur in the near future.

There has also been a sediment-related disaster caused by rainfall which blocked the national highway. The rain which started on December 22, 2006 caused six flood damages on the national highway in the Jordan Valley, bringing the traffic to be closed. In the South Shouna district, landslides occurred at 13 sites. Eventually national highway between the Dead Sea and Aqaba was closed. These disasters were reported in “Al-Rai” (a Jordanian daily) on December 24.

5. Formulation of Master Plan for Sabo Works in Arid land – a Case Study in Jordan –

5.1 Outline

When sudden torrential rain occurs in Arid land which has a scarce annual rainfall and has little vegetation cover, surface run-off removes a large amount of sediment easily from the bare land in the upper river basin. There also soil erosion occurs in agricultural land (there are many farmlands on the slope) and agricultural lands is washed away. The river beds, filled with accumulated sediment by past sediment movements, will become the potential sources area of sediment. The sudden sediment flow can lead to disasters in the downstream of basin. The rainwater, of course, go to downstream or the Dead Sea as unused water. On Arid land, it is crucial to utilize unused water and recycle it. The excessive sedimentation in the dams arises as problems of worsening water storage efficiency.

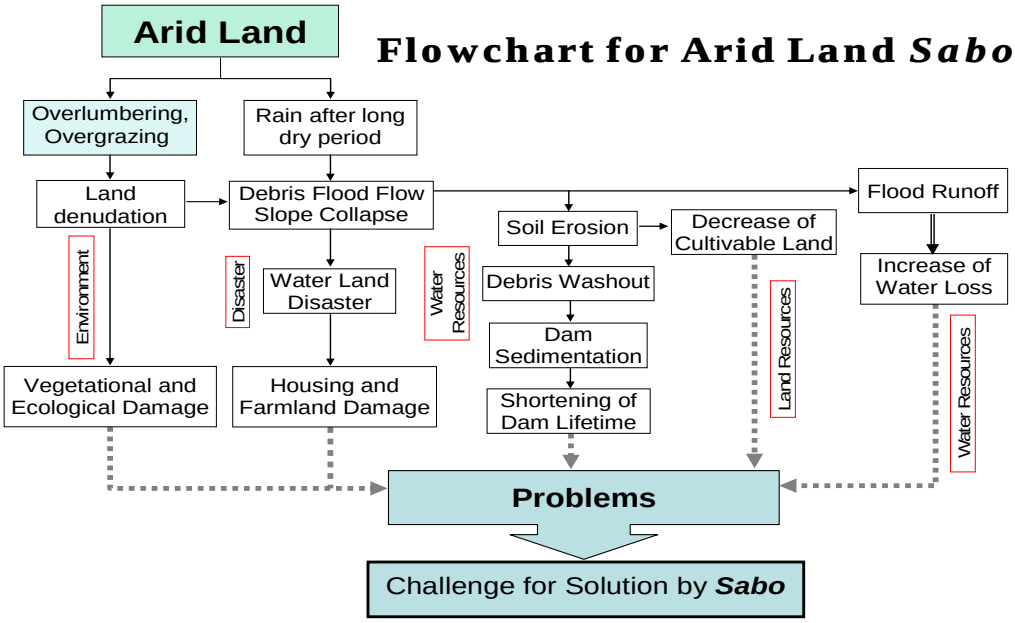

Fig-3 Problems in Arid land of Jordan

5.2 The general Idea of the Master Plan for Arid Land Sabo in Jordan

5.2.1 Points to be Considered as the Premise for the Master Plan

Due to the poor coverage of vegetation, entire areas of river basins are already in a condition which can easily cause the movement of sediment. Therefore, even light rainfall can move sediment and cause disasters in the basins.

The following are the important points to be considered when thinking about countermeasures.

The Sabo measures are easily introduced at the river heads because relatively flat areas are available on highlands. The Sabo work can also easily be done at the midstream and downstream areas because there are many open spaces in these areas.

With regard to rainfall forecasts, it is difficult for Jordan alone to predict the rainfall areas beforehand, for Jordan, a country neighboring other countries of Middle East Conflict, can only produce a fragment of regional observation data from its own territory. In the current situation, sharing weather information for the approaching disastrous weather is a difficult task. Therefore, forecasting rainfall in the context of disaster prevention is hard in Jordan.

The residents and administrative officials do not seem to think seriously that they are living in hazard zones and conducting development works where disasters may occur. They do not seem to have a concrete concept of evacuation, either.

It is necessary to make a Master Plan of Arid Land Sabo in order to prevent sediment-related disasters. These disasters are becoming common due to natural conditions and social conditions that are characteristic of Arid lands. The Master Plan of Arid Land Sabo should also include the effective use of the rainwater when it does rain, in addition, the utilization of run-off sediment and long-term afforestation.

Generally speaking, in arid region, observation data are not always enough for the precipitation, flood discharge, run-off sediment discharge in some target areas. These data are fundamental when deciding the scale of a sheme derived from Master Plan of Arid Land Sabo.

Therefore, it may be practical to work first on a tentative plan and a long-term plan by utilizing the precipitation data and estimating the water flow which caused disasters in the past, and then review the plans when enough data becomes available.

5.2.2 Tentative Plan

Formulating Master Plan and implementing the countermeasures certainly face very difficult issues to be overcome in terms of time and costs. On the other hand, disasters could strike some area imminently. Therefore, the following can be considered the tentative plan for a time span of several years.

1) Construct training levees and circle levees which protect important targets such as residences, airports and public facilities.

2) Produce hazard maps for the safety of people in residences and for vehicles on major roads, as well as implementing an alarm signaling system.

3) Implement the Arid Land Sabo measures which cover small areas of the river head using various technologies which are presently available in Jordan, wherever possible.

4) Regarding the wadis which have a large watershed basin, construct sand pockets and flood retarding basins at upstream and midstream areas so that the peak discharge of flood is reduced.

5) Regarding the wadis which have small basins, examine the shape of the alignment and the cross sectional area of wadi course downstream, in addition to the dispersion of water upstream and midstream. Secure the cross sectional area of river courses especially at the crossing point of roads.

6) Conduct surveys on the basins (in the basin of a water supply dam, conduct landslide investigations at upstream area as a first step) and collect the information. Launch an investigation on the hydrological and hydraulic data as soon as possible.

With regard to 1), the soil cement construction method will be applicable because aggregates (sand) and cement are readily available in Jordan. A construction method using stones can also be considered.

With regard to 2), soft-ware measures should be developed which include raising the awareness of people, using hazard maps, on the risks in new development areas, as well as for the measures to prevent damage to lives and vehicles. A wire sensor system can be employed instead of rain alarm system which is difficult to forecast.

Regarding 3), the Ministry of Agriculture and the Jordan Valley Authority have already been implementing small-scale catchment systems (contour trenching, masonry dam, earth dams, etc.), removal of surface impermeable layers and construction of Bi'r System (Photo 3, 4) in the highlands and valleys. It is necessary to implement these measures on highlands (river head areas) and on the slopes of valleys to the maximum extent.
These measures will enable dispersion and infiltration of rain water, the retention and storage of it, and reduction of the peak discharge in the downstream. It is also necessary to consider how to re-use water which was infiltrated and stored.

Photo-3 Small scale earth dam in High lands Zone

Photo-4 Contour terrace method on the slope of Jordan Valley

Regarding 4), there are vast unoccupied lands

particularly in the upstream and midstream areas of basins in Jordan. It is desirable to construct sand pockets and flood retarding basins, by utilizing this land to reduce the peak discharge and the flow velocity. It is also desirable to construct systems which enable the use of water from the flows even during flooding.

Regarding 5), securing sufficient cross sectional area for the wadi course, especially inside the Jordan Valley to the north of the Dead Sea, where sediment-related disasters are prone to happen.

Regarding 6), it is necessary to collect data properly in order to formulate a Master plan. However, there are challenges to overcome the differences of ministries and agencies, and also the projects cost. Therefore, it is necessary to establish a technical committee which consists of related organizations in order to tackle the obstacles in the data collection and other measures. In this committee, necessary discussions should be focused on what they can start with.

5.2.3 Long-Term Master Plan

1) Disaster Prevention Plan

This plan should be designed to ensure the safety of human lives, houses and properties in the target area, considering the characteristics of the basin. Scale of planning should be specified. The basic idea should be to reduce the peak discharge by dispersing and storing the rain water and running water. When planning a disaster prevention plan, the scale of sediment-related disaster area should be decided first, and a hazard map should be drawn for the area. By these works hazard zones will be specified and the targets to be protected should be decided.

The hazard map should be publicized in order to raise the awareness of the residents about disaster prevention, as well as to restrict further development scheme in the hazard zones.

The specific content which should be included in the Master plan is the following.

(1) In order to separate the water from the sediment, construct sand pockets and flood retarding basins in the upstream and midstream areas using open spaces, based on hydrologic and hydraulic analysis. It will also be effective to construct flood retarding basins inside the banks, in order to store water which exceeds a certain water level.

(2) Reinforce water dispersion (using infiltration and storage) at the river head (highland). It is particularly important to increase the size of Bi’r System by combining the use of subsidy systems.

(3) It is necessary to secure the cross sectional area of wadi course in downstream zone.

(4) Conduct thorough landslide-topography survey prior to construction of water supply dams. Build water dispersion works at the river head in order to retain sediment there and to reduce sediment deposit in the reservoir. Setting the Monitor system on landslides around the dam lake and introduce an alarm system for emergencies. Consider excavation/removal system for the sediment captured at the Sabo dams built upstream of reservoir.

2) Water Re-Utilization Plan

This plan should design effective utilization of rain water which has been collected and/or stored by the Sabo facilities at the river head. With regard to increasing the size of Bi’r System, use subsidy systems. The establishment of new water laws should be considered in which the share of water by land owners and the government will be determined in accordance with the subsidy rate. The water possessed by the individual can be used for agriculture and the water possessed by the government can be utilized for afforestation or as water supply in public projects. It will also be important to consider a system to collect surface run-off directly and to store the water in reservoirs.

3) Sediment Resource Utilization Plan

This plan should be made for utilization of the run-off sediment and to create new agricultural land.

4) National Land Afforestation Plan (New Oasis Plan)

This plan should be a long-term land afforestation plan, for which re-utilization water availed by the Sabo facilities is directed. Model areas should be set up for the plan.

In order to implement the Arid Land Sabo works in arid areas, it is essential to conduct education and public relations which will raise the awareness of people at all levels of society about disaster prevention in the country and in the areas that are covered by the Arid Land Sabo plan.
It will be extremely difficult to take countermeasures against sediment-related disasters using a single Sabo facility in a vast basin. Therefore, it is important to reduce the peak flow discharge and reduce the flow velocity by combining solutions in sub-basins, i.e. creating multiple small-scale catchments in the river head area. It is also necessary to utilize open spaces at midstream and downstream. This will require cooperation from the land owners.

5.3 Implementation and Evaluation of Arid Land Sabo Works in the Model Basin

Prior to the establishment of a National Arid Land Sabo Master Plan based on **Mater Plan for Sabo Works in Arid Land**, it is desirable to implement the countermeasures in model basins on a trial basis and to evaluate the effects of the countermeasures at floods.

Therefore, at the model basin, it is important to measure the precipitation, water flow discharge, the sediment discharge, etc. It is also important to amend the countermeasures to more effective ones based on the characteristics of wadi-flood; frequency of the flooding and the degree of disasters caused by the flooding.

6. Conclusion

The author had the opportunity to visit Jordan and observe the Sabo issues in arid land in Jordan. The author then came to the conclusion that countermeasures are necessary against disasters from sediment movements in Arid lands on a global basis.
This conclusion led the author to the above-described proposal on the approach to the Arid Land Sabo Works.
However, the problems which Arid lands face vary in different countries and regions. Therefore, it is necessary to understand the present situation and the problems first, and then consider the countermeasures to the problems.

Former Prime Minister Koizumi proposed the Japan's concept for creating the "Corridor for Peace and Prosperity" as part of supporting the regional peace building for Palestine Issue in July 2006 when he made a round of visits to the Middle East. This scheme indeed targets the Jordan Valley. It is thought that securing safety inside the Jordan Valley is necessary also for realizing this scheme.
I would like to end this paper, hoping that the Sabo works could contribute to reducing the damage caused by sediment-related disasters in Jordan.

References:
(1) World Atlas of Desertification: UNEP, Arnold, 1997
(2) Country Study for Japan's ODA to Jordan: JICA, 1996. 3
(3) National Water Master Plan, 2004: Ministry of Water and Irrigation, Jordan, 2004.6
(4) Outline of Jordan: JICA Jordan Office H/P

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