Chapter 2
Effect of Land Use Changes on Water Balance and Sediment Yield in Iran

Abstract Land use changes in response to water balance in Iran were studied. About 29 % of total land comprise of agriculture and considered one of most significant economic sector. In northern Iran, Gorganrood, a mountainous catchment comprehensively examined by using WetSpa model which comprises of topography, soil and land use maps to predict discharge hydrographs and spatial distribution of hydrological factors. Deliberated hydrological processes in the model are evapotranspiration, precipitation, depression storage, interception, surface runoff, percolation, interflow, infilteration, ground water flow and water balance in each layer of soil. Response of water balance in soil and water in Kanyanrood catchment, Lake Urmia basin, Karkheh catchment, sedimentations, sub-catchments also mitigated. Different models used in the study also discussed.

Keywords Agriculture · Hydrological processes · Interflow

2.1 Response of Water Balance to Land Use Changes in Iran

Iran is in the Middle East with an area of approximately 1.75 million km^2. Almost 510,000 km^2 land of Iran is allotted for the agriculture which indicates the 29 % of the entire land of Iran. The agricultural sector is one of the most significant economic sectors in Iran, and has extensively expanded in the last two decades as very large population is economically reliant on it. In 2007, agricultural yield contributed for 23 % of the Gross Domestic Product (GDP), 9 % higher than that of in 1992 (FAO 2008). Almost 90 % of the water resources are assigned to the agriculture sector (Ardakanian 2005). As it is represented by Fig. 2.1 that in 2004, 92.2 % of entire water withdrawal was supplied to the agriculture sector in Iran. Hence, with the increase in population size and higher demand for food, more land has been used for crop growth and there is a high pressure on natural resources, particularly water. Iran is one of the countries that have to pay grants to utilize resource, mainly water resources which attribute to the poor management in agriculture (FAO 2008).

© Springer Japan 2015

M. Hosseini and M.A. Ashraf, *Application of the SWAT Model for Water Components Separation in Iran*, Springer Hydrogeology,
DOI 10.1007/978-4-431-55564-3_2

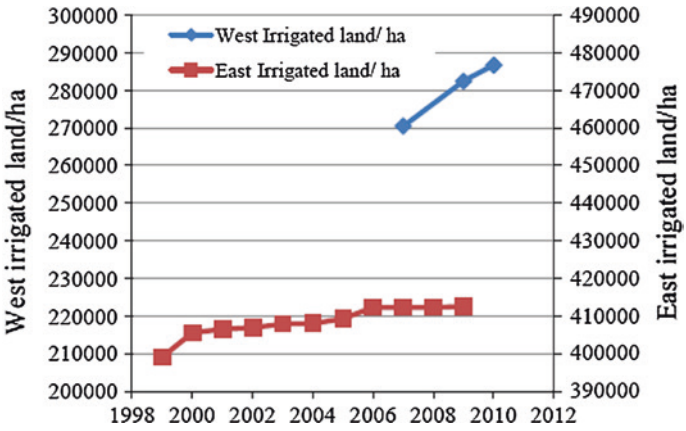


Fig. 2.1 East Azerbaijan and West Azerbaijan agricultural land, Lake Urmia Basin (Zulkifley et al. 2014)

2.1.1 Gorganrood Catchment

Gorganrood is mountainous catchment located in the northern Iran, Caspian coast (Fig. 2.2). Effect of land use changes on water balance and its components in Gorganrood catchment, Iran was comprehensively examined developing a spatially distributed hydrologic model (WetSpa) for the period of last two decades. This model comprises of topography, soil and landuse maps (Fig. 2.3) to predict discharge hydrographs and spatial distribution of hydrological factors. Figures 2.4 and 2.5 represent two resultant parameter maps, which are imperative for model simulation, i.e. potential runoff coefficient and flow travel time maps, respectively. For each grid cell the model holds water balance in the root zone by analyzing variations in soil moisture because of continuous alterations in infiltration of precipitation, runoff, initial absorption, evaporation transpiration, interflow, and percolation to the groundwater zone. The model provides all flow modules at any cell, comprising surface flow, interflow and groundwater flow.

The deliberated hydrological processes in the model are evapotranspiration, precipitation, depression storage, interception, surface runoff, percolation, interflow, infiltration, groundwater flow, and water balance in each layer. A schematic representation of the considered hydrological processes can be seen in Fig. 2.6.

Isolated water balance for the vegetated, bare-soil, open water and impermeable share of each cell accounts for entire water balance for each raster cell. For each grid cell, the modeling of root zone water balance is performed constantly by associating inputs and outputs determined by Eq. (2.1).

$$D\Delta\theta/\Delta t = P–I–V–E–R–F \tag{2.1}$$

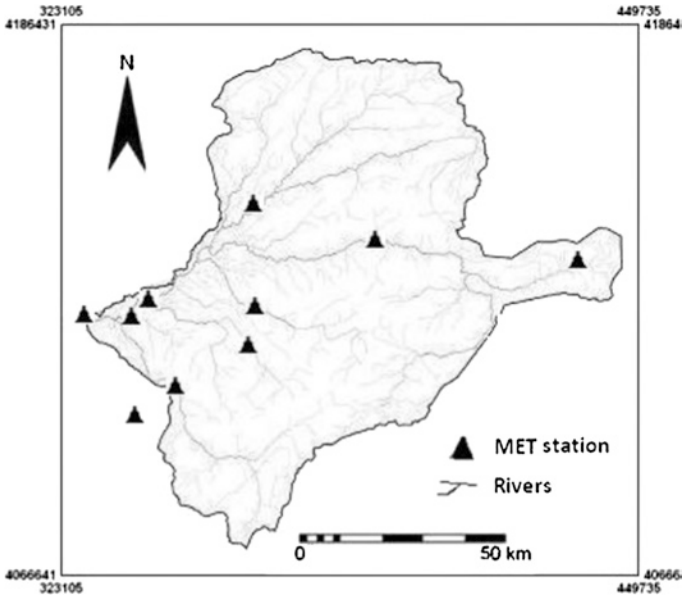


Fig. 2.2 Location of Gorganrood basin, with main tributaries and stations

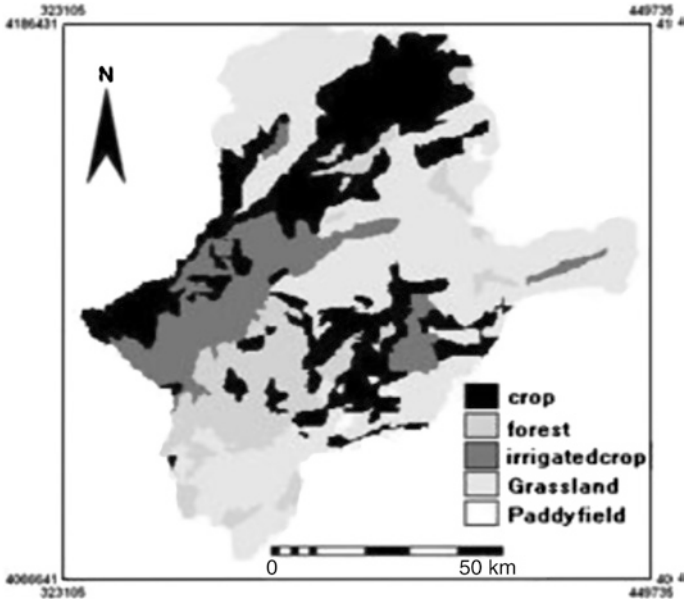


Fig. 2.3 Land use map of the Gorganrood basin

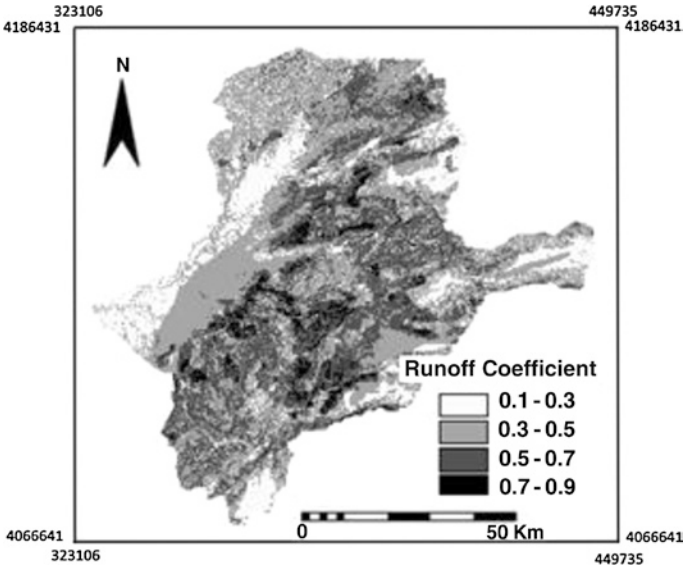


Fig. 2.4 Potential runoff coefficient map of the Gorganrood basin

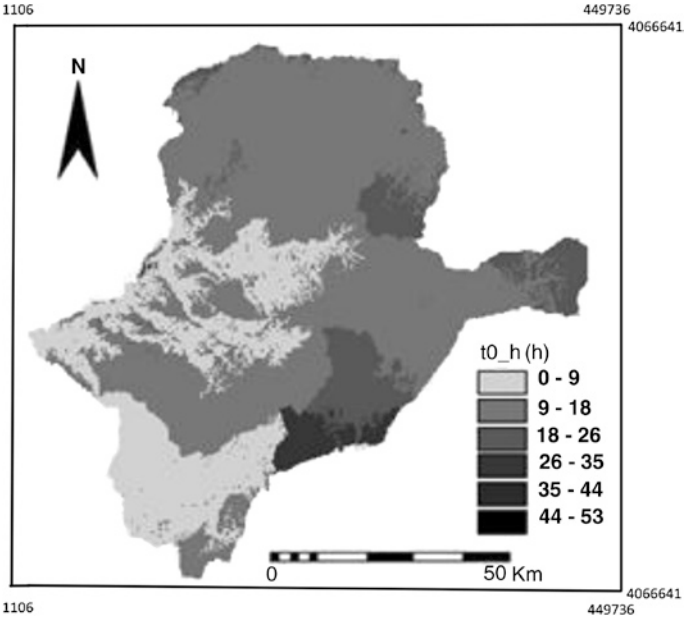


Fig. 2.5 Flow travel time of the Gorganrood basin

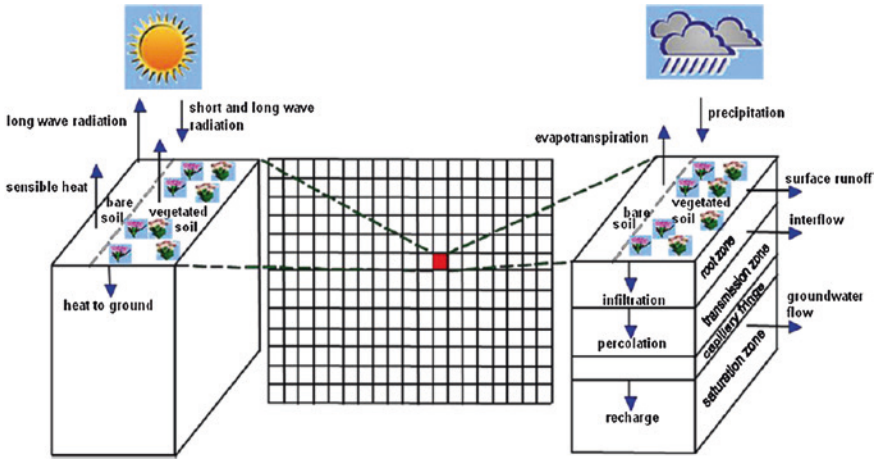


Fig. 2.6 WetSpa model structure

where D [L] is the root depth, Δθ [L3L-3] is the alteration of soil moisture, Δt [T] is the time interval, I [LT-1] is the initial perception comprising interception and depression losses within time step Δt, V [LT-1] is the rate of surface runoff or rainfall excess, E [LT-1] is the actual evapotranspiration from the soil, R [LT-1] is the filtration out of the root zone, and F [LT-1] is the concentration of interflow in depth over time. The rainfall excess is measured applying a moisture-related altered rational technique with possible runoff coefficients reliant on land cover, soil type, slope, the extent of rainfall, and the precursor soil moisture. In the case of surface layer, actual evapotranspiration is calculated as an area-weighted mean of the land use percentage. The course-plotting of overland flow and channel flow is employed by the process of the diffusive wave approximation of the St. Venant equation (2.2):

$$\frac{\partial Q}{\partial t} = d\frac{\partial^2 Q}{\partial x^2} - c\frac{\partial Q}{\partial x} \tag{2.2}$$

where Q [L^3T-1] is the discharge at time t and location x, t [T] is the time, x [L] is the distance along the flow direction, c [LT-1] is the location dependent kinematic wave celerity and is interpreted as the velocity by which a disturbance travels along the flow path, and d [L^2T-1] is the location dependent dispersion coefficient, which expresses the tendency of the disturbance to disperse longitudinally as it travels downstream. supposing that the hydraulic range lines the deepness of the average flow for overland flow and waterways, c and d can be estimated by c = (5/3)v, and d = (vH)/(2S0), where v [L/T-1] is the flow velocity measured by the Manning equation, and H [L] is the hydraulic range or average flow depth. Model was calibrated for the investigated catchment area for the duration of 1983–1989, whereas the duration from 1990 to 1995 was implemented for model validation.

Assessment of the result illustrates that the plant canopy interrupted 6.22 % of the precipitation, 90.19 % penetrates to the soil, 84.41 % evapotranspiration to the atmosphere, 12.43 % recharges to the groundwater reservoir, and 15.83 % converts into runoff, of which 2.71, 1.15 and 11.97 % forms the surface flow, interflow, and groundwater flow, respectively. Furthermore, these calculated amounts are equitable related to the hydrological properties of catchment.

Annual changes in water balance and its modules (mm) have been described comprehensively in Table 2.1. The flow (R) involves the surface runoff (RS), interflow (RI) and groundwater flow (RG). Different modules of the computed flow in association with rainfall are presented in Fig. 2.7 (Kabir and Bahremand 2011).

2.1.2 Zanjanrood Catchment

The hydrological impacts of land-use change in Zanjanrood basin, Iran were explored in order to make useful strategies for sustainable availability of water resources. The simulation of water balance was performed employing the Soil and Water Assessment Tool (Ashraf et al. 2014). Model calibration and uncertainty assessments were conducted applying sequential uncertainty fitting (SUFI-2). Data obtained by simulation study from January 1998 to December 2002 were provided for further parameter calibration, and after this the model was certified for the period of January 2003 to December 2004. The expected monthly streamflow coincided with the observed values: throughout calibration the correlation coefficient was 0.86 and the Nash–Sutcliffe coefficient 0.79, compared with 0.80 and 0.79, respectively, during validation. With the intention of investigation of impacts of land-use changes in 1967, 1994 and 2007, the model was employed to simulate the key modules of the hydrological cycle. The results illustrate that throughout 1967 a 34.5 % reduction of grassland with simultaneous upsurges of shrubland (13.9 %), rain-fed agriculture (12.1 %), bare ground (5.5 %) irrigated agriculture (2.2 %), and urban area (0.7 %) resulted in a 33 % rise in the magnitude of surface runoff and a 22 % drop in the groundwater recharge. Additionally, the area of subbasins which was affected by intensive runoff enlarged from 14 to 28 mm. The consequences point out that the hydrological retort to overgrazing and the substituting of rangelands (grassland and shrubland) with rain-fed agriculture and bare ground (badlands) is nonlinear and manifests a threshold impact. The runoff intensifies radically when clearing of rangeland exceeds 60 %. Conversely, groundwater suppressed by 80 % in rangeland (Ghaffari et al. 2009).

2.1.3 Lake Urmia Basin

The Lake Urmia basin is located in the North West of Iran with high mountain areas, foothills, and plains. It is a closed drainage basin (i.e. no outlet) with an area

Table 2.1 Modules of water balance estimated for each year

Year	Rainfall (mm)	Interception (mm)	Soil moisture (mm)	Infilteration (mm)	Evapotranspiration (mm)	Percolation (mm)	RS (mm)	RI (mm)	RG (mm)	R (mm)
1983	278	25.75	250	256	304	12.9	5.2	1.45	26.94	34
1984	301	21.31	245	367	358	31.8	10	3.73	30.43	44
1985	256	25.96	248	291	285	33.1	7	2.77	31.48	41
1986	301	26.1	252	384	372	37.5	9.1	3.38	32.17	45
1987	355	32.67	257	434	385	81.3	17	7.92	67.74	92
1988	336	29.53	257	440	400	61.9	14	6.18	62.75	83
1989	257	22.11	250	355	319	43.7	8.4	3.84	41.86	54
1990	296	25.34	248	321	327	38	8.3	3.39	36.82	49
1991	325	23.28	247	389	360	50.5	11	4.45	45.01	60
1992	377	34.32	258	566	461	131	24	12.7	110.9	147
1993	310	26.28	250	419	389	53.2	13	5.14	54.14	72
1994	287	27.1	256	397	350	57.3	11	4.76	57.02	73
1995	267	28.2	249	329	347	29.5	7.6	2.34	33.3	43

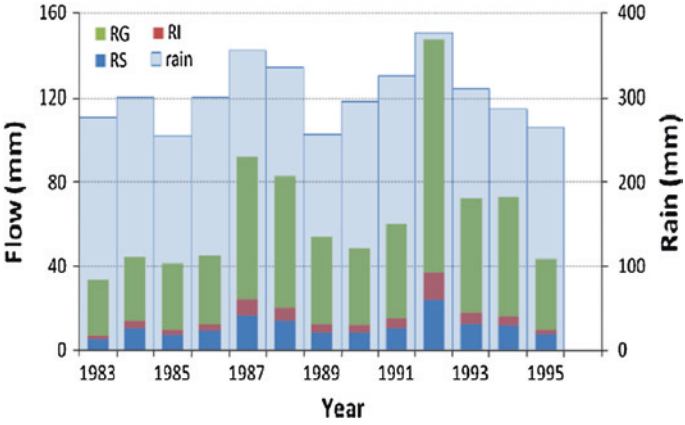


Fig. 2.7 Comparison between different estimated flow modules and rain quantity

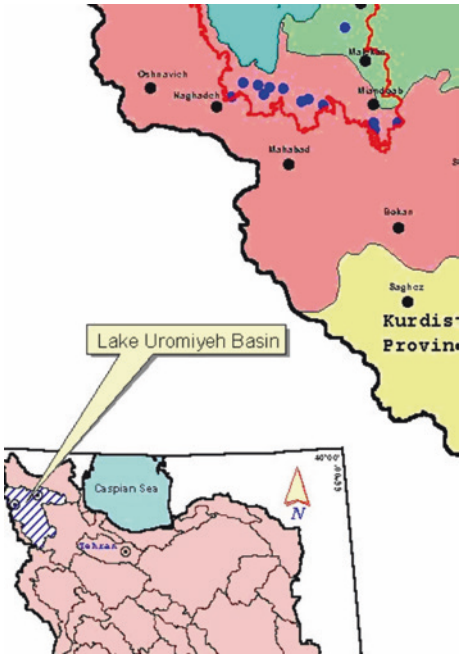


Fig. 2.8 Lake Urmia basin map (Sima and Tajrishy 2013)

of about 51,876 km^2 (Fig. 2.8). Lake Urmia basin is just about 3 % of the total area of Iran (FAO 2008), with about 51,876 total km^2 and 18,702.86 km^2 agricultural lands in East Azerbaijan and West Azerbaijan, respectively (Ardakanian 2005). In the Lake Urmia Basin, increasing population, socio-economic progress and the enlargement of farming land to supply foodstuff have resulted water scarcity.

As irrigation has intensified in both West Azerbaijan and East Azerbaijan, so the water accessibility in the downstream regions has been rigorously reduced. The intensive cultivation on acreage after the hydrometric stations could be deliberated as one of the key complications to calculate the volume of water delivered to the Lake (Sima and Tajrishy 2013). Release of water from the rivers and canals are problematic as well, and the recent droughts in the area have had substantial influence on rivers influx and lake water balance. For example, in recent years, no water inflow to the lake from the Mardogh Chai River was noticed after establishment of Baba roud station (Sima and Tajrishy 2013).

From 1969 to 1998, the area of lake surface has been comparatively persistent (5300 km^2) (Fig. 2.9) (UNEP 2012). Since 1998, the lake size has been reduced to the less than its half size. According to satellite data, its area condensed to around 2366 km^2 in August (Fig. 2.9) (UNEP 2012). In 1995 highest water level was recorded in Lake Urmia and exceeding 1277.49 m of sea level (Fig. 2.10) (Natural Resources and Watershed Management Organization 2011). As it is clear in an aerial photographs in Fig. 2.10, the surface area of Lake Urmia basin has reduced in generally at the south and east position during 2006 and 2011. Decreasing of the Lake surface area could be address to the reduced water influx to the lake exactly from mid 1990s which water level affectedly has declined up to present-day (Fig. 2.10 and Table 2.2).

The entire watercourses and streams reach to this lake has been desiccating at very fast rate since 1990. The maximum lake water level noted was 1277.80 m in 1994 whereas it was dropped up to 1271.58 m in 2008. The lake water capacity has altered throughout the investigation period and displays a reduction from 32 to 14.5 million m^3, while the lake salinity went up from 205 to 338 g L^{-1} because of the high evaporation rate and low water influx. Regarding Lake Urmia basin, there has been an increase in public wakefulness of the emerging water scarcity, environment and all the challenges that could definitely become crisis for the native people of that area.

2.1.4 Karkheh Catchment

An inclusive spatio-temporal evaluation of the surface water resources of the semi-arid Karkheh basin, Iran was performed which subsequently facilitates policy makers to do efforts for sustainable water development in that area. The investigation is on the basis of the consideration of statistical parameters, flow interval features, base flow separation and trend analysis and for this purpose data collected from seven main gauging stations (Fig. 2.11) were employed from 1961 to 2001. In addition, basin level water accounting was done for the water year 1993–1994. The results illustrates that detected daily, monthly and annual streamflows are extremely flexible in space and time within the basin (Fig. 2.12). The streamflows have not been altered considerably when measured at annual basis; nevertheless major trend has been exhibited for few months, most particularly a drop for the

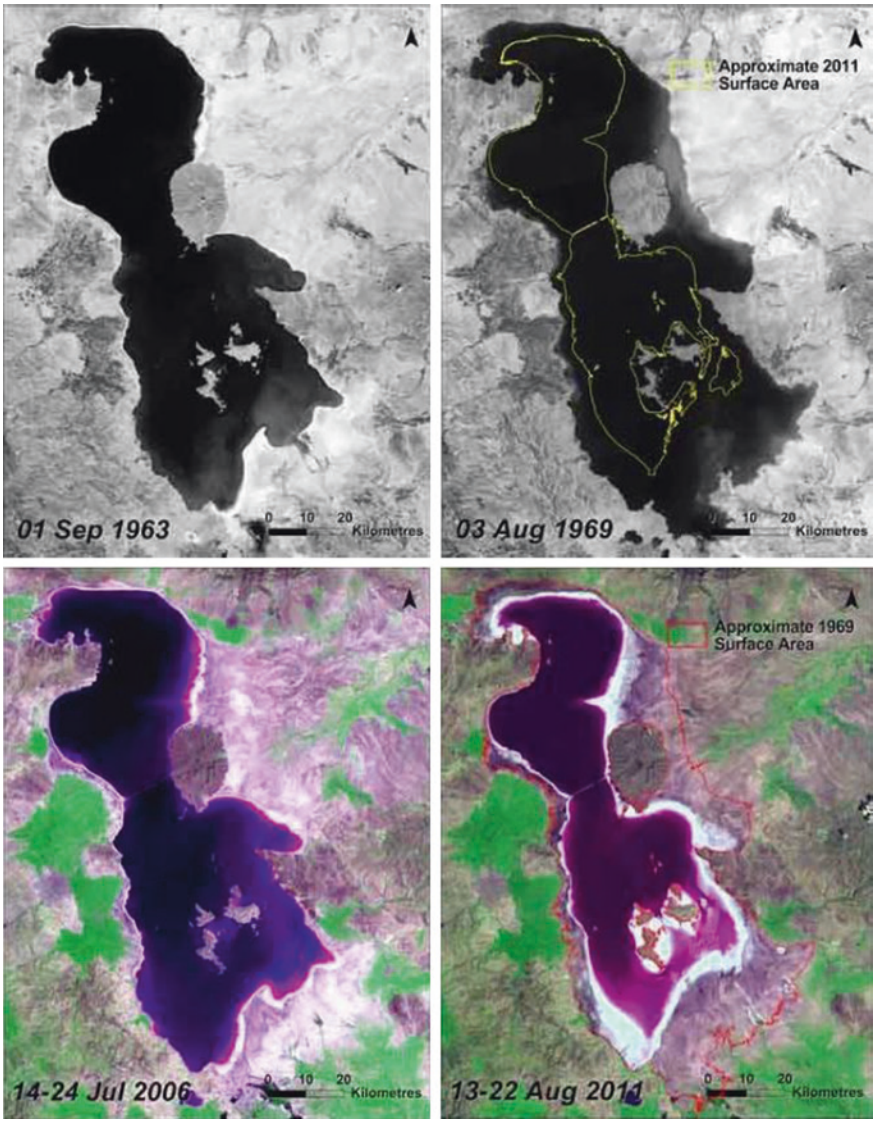


Fig. 2.9 Landsat image of Lake Urmia (*Source* 1963 Image: ARGON data from USGS; 1969 image: Corona data from USGS, visualization by UNEP GRID Sioux Falls; 1972–2011 images: Landsat data, 2011 image: visualization by UNEP GRID Sioux Falls

period of May–June and a rise for the duration of December–March. Figure 2.13 shows that hydrograph peaks occur in March and April roughly one month in the lag of precipitation. Snow melting in the winter season and contribution of water after passing through different waterways such as ground water is a major source of streamflow. The key reasons involved the climatic variations, land use and

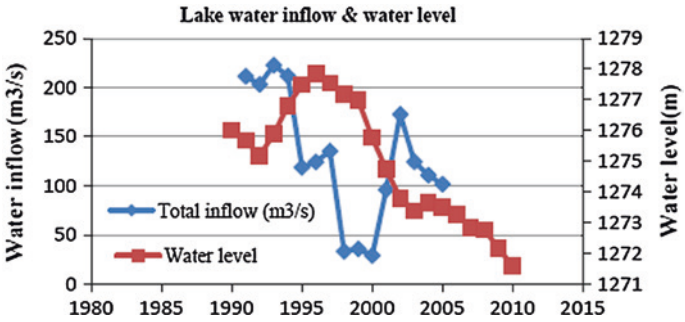


Fig. 2.10 Lake water inflow and Lake water level. Data from Natural Resources and Watershed Management Organization (2011)

Table 2.2 The water inflow to the Lake Urmia Data from (Sima and Tajrishy 2013)

Year	1978	1986	1993	1998	1999	2000
Water inflow to the Lake (MCM)	13,526.7	10,725.82	8845.49	586.34	439.97	341.2

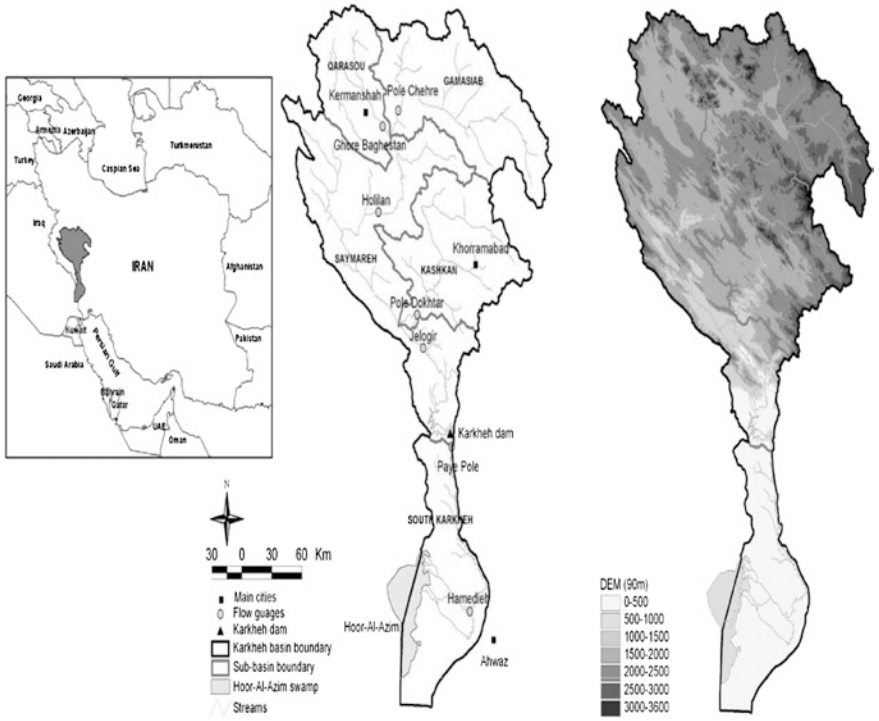


Fig. 2.11 Location of Karkheh basin with seven gauging stations

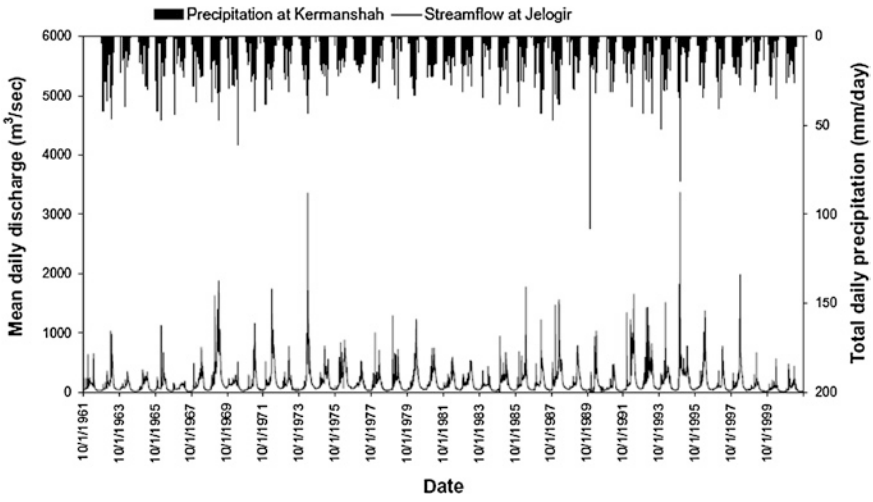


Fig. 2.12 Average yearly variability daily streamflow during 1961–2001

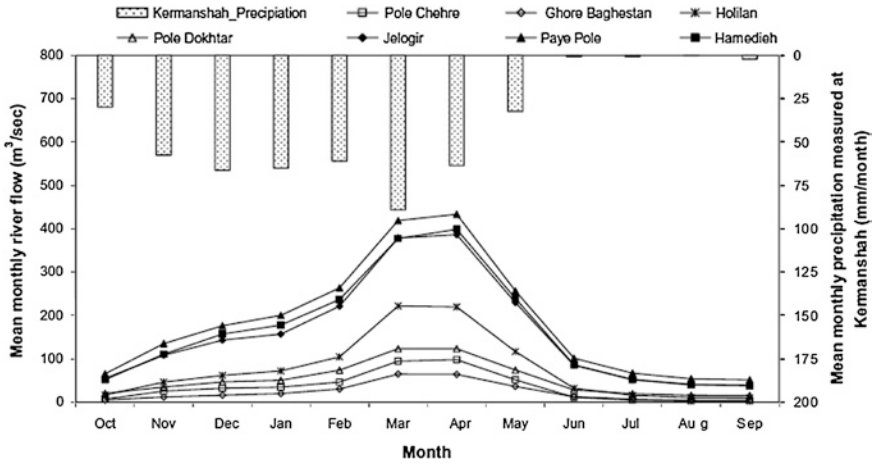


Fig. 2.13 Average monthly discharge in study area of Karkheh basin, Iran

reservoir practices. The study accomplishes that the water distributions to various sectors were lesser than the entirely accessible resources throughout the investigation period (Fig. 2.14). Though, regarding the large variability of streamflows, climatic variations, land use and current water resources development practices, it will be enormously challenging to full fill the requirements of all sectors in the upcoming years, predominantly in the course of dry season (Masih et al. 2009).

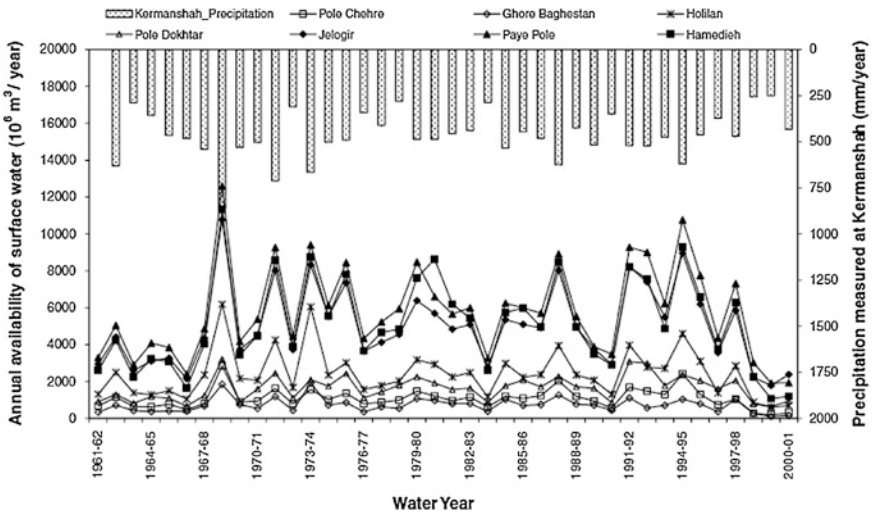


Fig. 2.14 Long-term variability in yearly surface water availability in Karkheh basin, Iran

2.2 Response of Sedimentation to Land Use Changes in Iran

One of the most important concerns in arid and semi-arid areas, Iran is water erosion and sediment transport. Soil particle transmission from farm and orchards to other areas causes the fertility of such lands decreases gradually (Sarmadian et al. 2010). Deforestation in Iran has been more rapid in the past 50 years than at any time in Iran's history. Intensive cultivation and mismamnagement have caused environmental problems and soil degradation (Bakar et al. 2015). Moreover, sedimentation in water channels clogs the water ways; it may also transfer pollutants into farm lands and dams, which are used for irrigation and drinking purposes (Sarmadian et al. 2010).

Erosion causes serious consequences for economy as well as the environmental productivity. The important influences of soil erosion are manifest in areas which don't have erosion but suffer from its consequences by sediment deposition in watercourses and reservoirs, water quality and flow rate decreasing (Gharibreza et al. 2014). All these results have a negative impact on water of river regimes. There are many erosion classifications available in the literature review. Since water erosion is the most significant problem in western Iran, Surface erosion and mass movements in the catchment body, produce the soil loss which is due to its moving to another area as sediment. Development strategies led to changes in land use which exposed sensitive geological formations, consisting largely of shale and marl, to soil erosion. Moreover, poor vegetation cover in the Zagros Mountains was one of the main factors which caused millions of tons of soil to be transported by water to downstream catchments. Surface erosion and sediment yield are important factors that should be taken into account in planning renewable natural resource

projects. The Zagros mountain range begins in northwestern Iran and roughly corresponds to Iran's western border, and it spans the whole length of the western and southwestern Iranian plateau, ending at the Strait of Hormuz.

2.2.1 *Sub-catchments (Amrovan, Atray, Ali Abad, Ebrahim Abad, Royan)*

Several experimental models were used for predicting the erosion severity and sediment yield in a sub-catchment area. Response erosion severity and suspended sediment yield to land use changes of five small catchments (Amrovan, Atray, Ali Abad, Ebrahim Abad, Royan), Semnan Province, Iran (Fig. 2.15) were assessed implementing PSIAC model using consistent sediment yield data dumped in reservoir built in the outlet of these catchments (Gharibreza et al. 2013a). A strong positive correlation was found between Upland erosion and Specific Sediment Yield i.e. $r_2 = 0.86$.

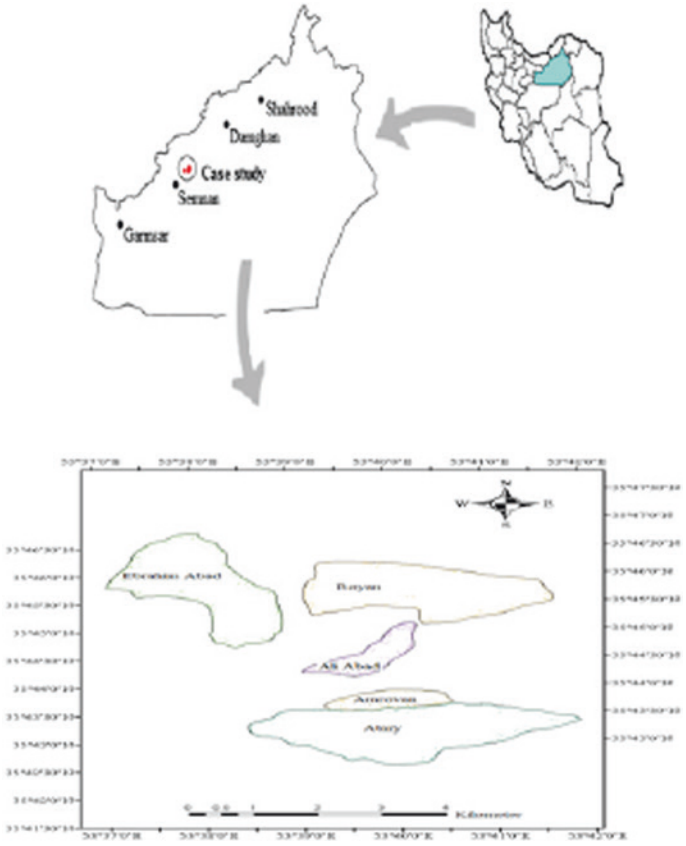


Fig. 2.15 Location of five sub-catchments (Amrovan, , Ali Abad, Ebrahim Abad, Royan)

Table 2.3 Scores and coefficient of different PSIAC factors and the quantity of predicted SSY in the study catchments

PSIAC factors	Catchments				
	Amrovan	Atray	Ali Abad	Ebrahim Abad	Royan
Surface geology (y1)	5.99	5.76	5.74	5.18	5.66
Soil type (y2)	4.28	3.43	1.97	4.35	4.65
Climate (y3)	1.12	1.12	1.12	1.12	1.12
Runoff (y4)	0.71	1.21	0.72	1.14	1.20
Slope (y5)	3.76	5.26	5.35	9.67	7.90
Ground covers (y6)	16.03	13.80	15.36	13.90	11.4
Land use (y7)	17.67	16.77	18.58	17.95	17.41
Upland erosion (y8)	16.58	6.20	7.08	5.40	7.85
Channel erosion and sediment transport (y9)	4.09	0.00	1.51	0.00	5.03
Total score (Pt)	70.23	53.55	57.43	58.71	62.22
Rating class	3	3	3	3	3
Predicted SSY (t ha^{-1} $year^{-1}$)	3.171	1.74	1.99	2.09	2.35

This method involves nine parameters that rely on surface geology, soils, climate, runoff, topography, ground cover, land use, channel erosion, and upland erosion. Each parameter is divided into various definite categories, and dependent on the extent of influence of each parameter category; a weighting value is allotted to each category using the model tables (PSIAC 1968).

Nine PSIAC parameters have been rated on the basis of PSIAC Guide Tables for investigation of catchments which can be seen in Table 2.3. The totalities of the calculated values for the suitable properties of the nine parameters generated the total score (Pt) and rating class for the catchments, and then followed by putting of a linear regression between Pt and the detected value of suspended sediment yield to calculate predicted suspended sediment yield. Equation 2.3 can be used to calculate specific sediment yield.

$$SSY = 4.119\,Pt + 55.31 (R2 = 0.755) \tag{2.3}$$

where, specific sediment yield is denoted as SSY (t ha^{-1} $year^{-1}$), PSIAC total score as Pt which is found by summing each discrete parameter (Table 2.3).

The findings of this investigation point out that all of the catchments are associated with modest rating class of suspended sediment yield i.e. class 3. Amrovan sub-catchment was found to have maximum magnitude of PSIAC predicted suspended sediment yield (3.171 t ha^{-1} $year^{-1}$), on the other hand it was minimum (1.74 t ha^{-1} $year^{-1}$) for Atray sub-catchment.

In order to evaluate relationship between nine PSIAC parameters and suspended sediment yield for different catchments, linear regression and correlation analysis was performed for detected suspended sediment yield and the score of each parameter for the catchments (Fig. 2.16). Surface geology has significant influence (Fig. 2.16a), due to great distinctions in erodibility of geological

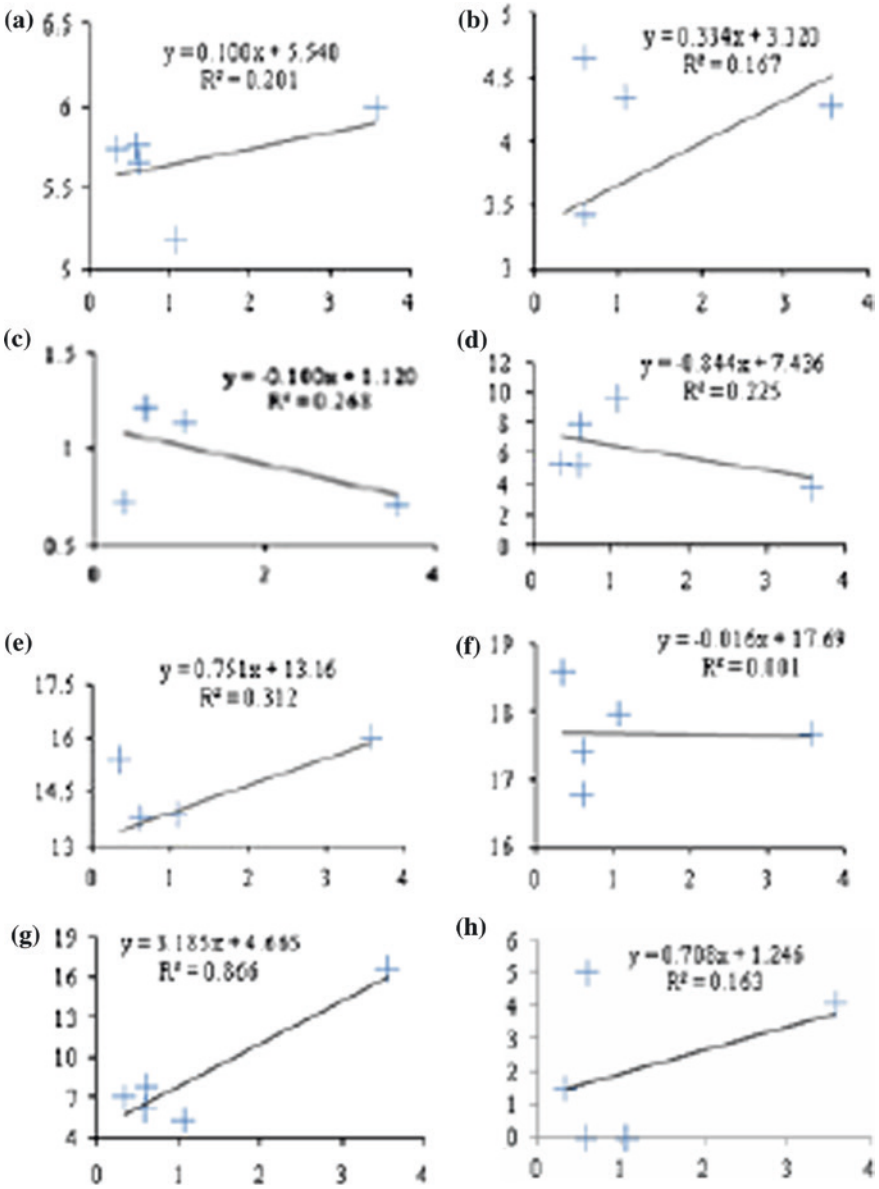


Fig. 2.16 Relation concerning each PSIAC scores and observed suspended sediment yield. Horizontal diagrams are observed suspended sediment yield (t ha^{-1} $year^{-1}$) and vertical diagrams are individual PSIAC scores. **a** Surface geology, **b** soil type, **c** runoff, **d** slope, **e** ground cover, **f** land use, **g** upland erosion and **h** channel erosion and sediment transport

materializations in the catchments. For instance, Amrovan and Royan catchments contain highly weathered constituents such as marl and quaternary whereas rest of the catchments (Ebrahim Abad, Atray) have a more resilient geology for example Azarin rocks.

The catchments under investigation showed distinction based on soil texture (Fig. 2.16b). Therefore, impact of soil is in range of low to moderate in zones where there is maximum to minimum stone coverage and moderate to high in zones where there is a soil that is categorized between moderate to single grained textured soils. The erodibility of a soil is affected by stony layer (Poesen et al. 1994; Nyssen et al. 2001) and grain dimension (Morgan 1986; Evans 1980).

Furthermore, runoff is an imperative factor in clarifying suspended sediment yield variability between the catchments (Fig. 2.16c). Runoff is further influenced by other factors (land use, soil and water conservation practices, slope, lithology and soil conditions) (USDA-SCS 1964). Topography exhibits comparatively strong impact on the changeability of specific sediment yield (Fig. 2.16d); though most of the regions of Amrovan, Ali Abad and Atray catchments are categorized based on steep upland slopes i.e. >20 % and in the Ebrahim Abad and Royan these are higher slopes i.e. <20 %. The effect of topography may be partially concealed by collaboration of impacts. Since stoniness may be anticipated to upsurge with degree of slope, the impacts of slope steepness and soil cover on erosion may neutralize each other (Haregeweyn et al. 2005).

The land cover is highly interrelated with suspended sediment yield (Fig. 2.16e). The influence on suspended sediment yield changeability is strong as a number of catchments stay ploughed and bare during rainy season (e.g. Amrovan), Though others are significantly safe because of being well covered. The impact of vegetation cover in decreasing soil erosion has been proved by conducting research related to vegetation cover: for instance cover associated with interception and cover in directly connected with the soil layer such as the impact of remains of crops (Morgan 1986) and stones (Nyssen et al. 2001). Besides interception, land cover disperses the energy of surface runoff by enhancing unevenness (Morgan 1986).

A weak correlation exists between land use and SSY (Fig. 2.16f), primarily due to insignificant land use changes across the catchments; above 90 % of the zone of most of these catchments consist of rangeland. Upland erosion and suspended sediment yield are highly interrelated (Fig. 2.16g) in these catchments, erosion takes place by rill, inter-rill and some gully erosions. Even though rates of erosion are suppressed in the catchments having prevailing shrub land and well stone cover: for example Ebrahim Abad and Atray catchments, a number of catchments like Amrovan the proportion of shrub and stone cover is very poor. Channel erosion is also representing some variable clarifying suspended sediment yield (Fig. 2.16h) in our study catchments there are no large waterways. Conversely in the Amrovan and Royan there are some small and not well developed waterways. The sediment yield from waterways is generally due to the occurrence of very erodible parental constituents such as marl in the case of this catchments and because of the vertices property of clay developments (Gharibreza et al. 2013b)

that are vulnerable to penetrating that results in bank flop and vigorous head cuts (e.g. Amrovan). Henceforth, importance should be given to recovering the waterways and the routed sub catchments while planning soil and water management practices in the catchments.

The analysis illustrates that suspended sediment yield differs considerably between catchments, i.e. from 3.57 to 0.35 t ha^{-1} $year^{-1}$. The remarkable spatial variability in suspended sediment yield is primarily related with dissimilarities in lithology, runoff, topography, ground cover and upland erosion.

2.2.2 Karkhe Catchment

In recent times, Karkhe watershed (KW) with size above 5 million ha faced many complications in the natural, social and man-made habitats. Improper land practices, soil erosion and shortage of rainfall are the most critical issues in this watershed disturbing the entire area basically. As anticipated, these complications have resulted in a substantial decrease in biodiversity in fauna and flora, a decline in capacity and excellence of water resources in watershed and intensification in possibility of destructive overflows. With the aim of investigation related to land use variations and soil erosion in 5 sub-regions of Karkhe watershed, LANDSAT images were developed for two periods of time '1988 and 2002'. The impacts of these operations on the physico-chemical properties of water like cation and anion level, acidity and salinity were determined. It was concluded that erosion variations in Karkhe Watershed are negligible from 1988 to 2002. The range of urban area and irrigated agricultural lands in Karkhe sub-regions (Gamasiab, Gharresu Kashkan) are about 1000 and 2000 km^2 correspondingly, the drop in river discharge almost 121.6 m^3 s, is the highly effective parameter for the drop in acidity from 7.9 in 1988 to 8.1 in 2002, an increase in salinity from 1.6 mg L^{-1} in 1988 to 3.6 mg L^{-1} in 2002 as average quantity of SAR in all sub-regions of watershed and the high density of the anions from 8.1 mg L^{-1} in 1988 to 16.4 mg L^{-1} in 2002 and cations from 8.8 to 16.5 mg L^{-1} in Karkhe River. According to the deputy of watershed management, Jihad agriculture in Iran, in 2004 the key concern in this area is the conversion of lands into geologically erodible lands which forms over 79 % of the entire watershed consequently generating sediment at about 1.5 million m^3 $year^{-1}$ that discharges directly into the Karkhe catchment (Mahmoudi et al. 2010).

2.2.3 Chamgardalan Catchment

Chamgardalan catchment is one of the sub-catchments of Karkheh watershed with the size 583.7 km^2 (Fig. 2.17). This watershed is positioned between latitudes 33° 23′N to 33° 40′N and longitudes 46° 16′E to 46° 40′E. GIS (ArcGIS9.3) was used for erosion intensity maps and the quantification of sediment yield/transport as

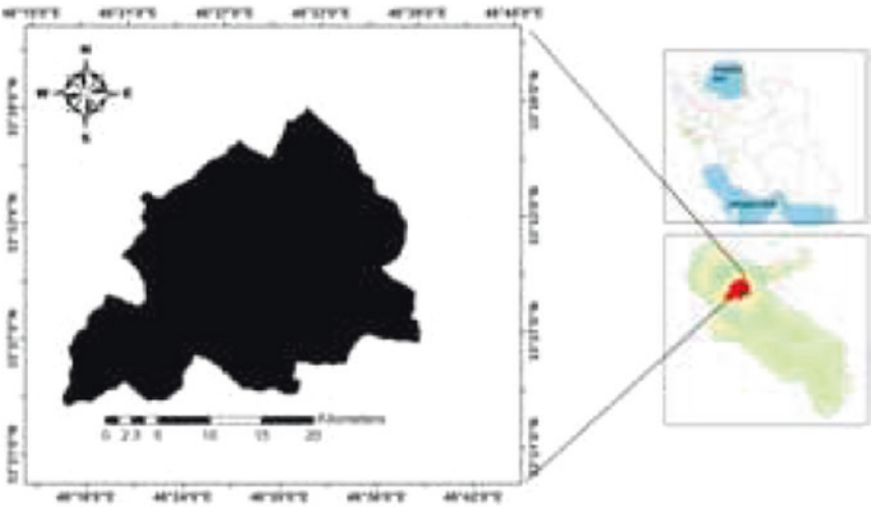


Fig. 2.17 Location of Chamgardalan catchment

well (Fig. 2.18). Description of the coefficient maps (Xa, Y, φ and j) was on the basis of spatial input data, viz. land use/land cover map (Fig. 2.19), DEM (Digital Elevation Model) (Fig. 2.20), geology of area (Fig. 2.21), and satellite images of area. The Y coefficient map represents the soil confrontation to erosion which is developed on the basis of geology and soil data.

By using EPM method, average yearly catchment Degradation Wsp (average yearly sediment yield) is determined by means of the following Eq. (2.4):

$$Wsp = T \times h \times \pi \times (aZ^3 \times F)(\mathrm{m}^3\ \mathrm{year}^{-1}) \tag{2.4}$$

where h (mm) indicates average yearly rainfall, F represents catchment area (km^2) and T signifies the temperature coefficient and t is average yearly air temperature (°C).

Erosion coefficient Z can be calculated by Eq. (2.6).

$$T = \left(\frac{t}{10} + 0.1\right)^{1/2} \tag{2.5}$$

$$Z = Y \times Xa \times (\varphi + j) \tag{2.6}$$

where Y: indicates Coefficient of the soil confrontation to erosion (functions of geology and soil type), X: indicates Land use/land cover coefficient, a: represents conservation coefficient after an erosion estimates (here a = 1), φ: indicates coefficient of the observed erosion process (takes into consideration clearly detectible erosion processes), j: indicates average slope of the catchment.

$$R = \frac{4(P \times D)^{1/2}}{L + 10} \tag{2.7}$$

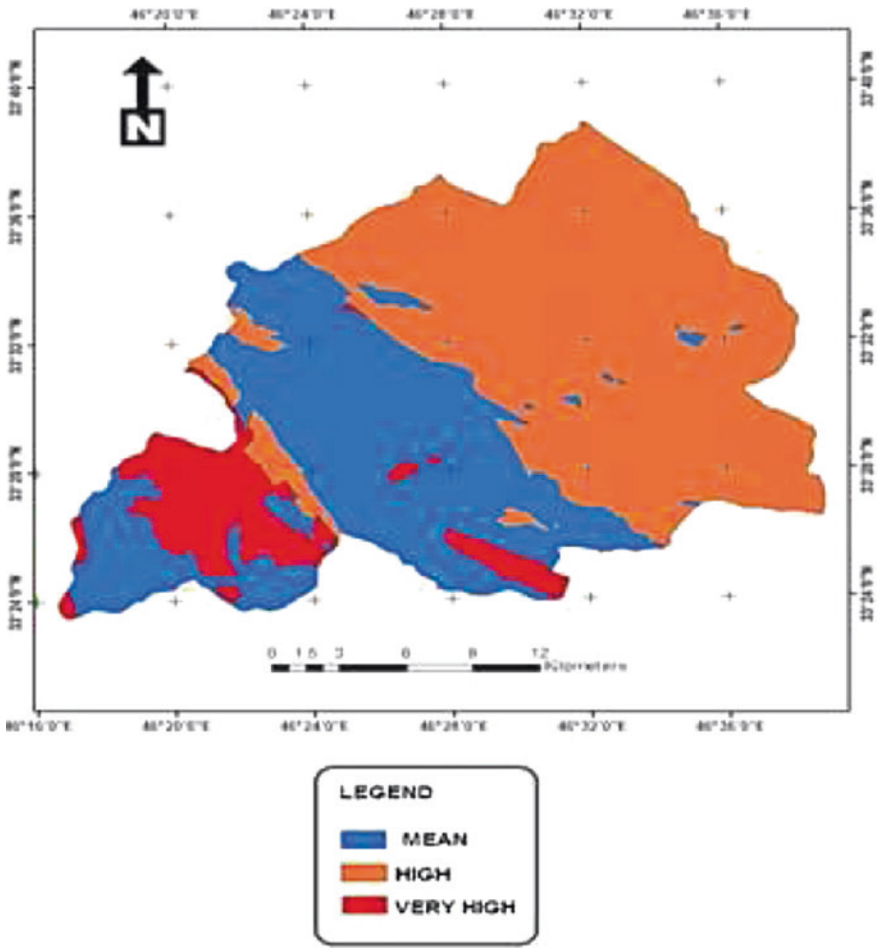


Fig. 2.18 Erosion quality map of Chamgardalan catchment

R is coefficient of sediment formed in any homogenous units,
P Perimeter of the homogenous unit (km),
L Length of the homogeneous unit (km),
D Average altitude gradient (km).

Finally, *Gs* symbolize the average yearly sediment amount that enters the detected cross-section which is calculated by multiplying Eqs. (2.4), and (2.7) as indicated by Eq. (2.8).

$$G_s = T \times H \times (Z^3) \times F \times R \ (\mathrm{m}^3 \ \mathrm{year}^{-1}) \tag{2.8}$$

All EPM functions are determined in homogeneous unit (Fig. 2.22).

The main objective of the study was qualitative and quantitative estimation of the erosion and sediment yield of Chamgardalan watershed, Ilam Iran by applying

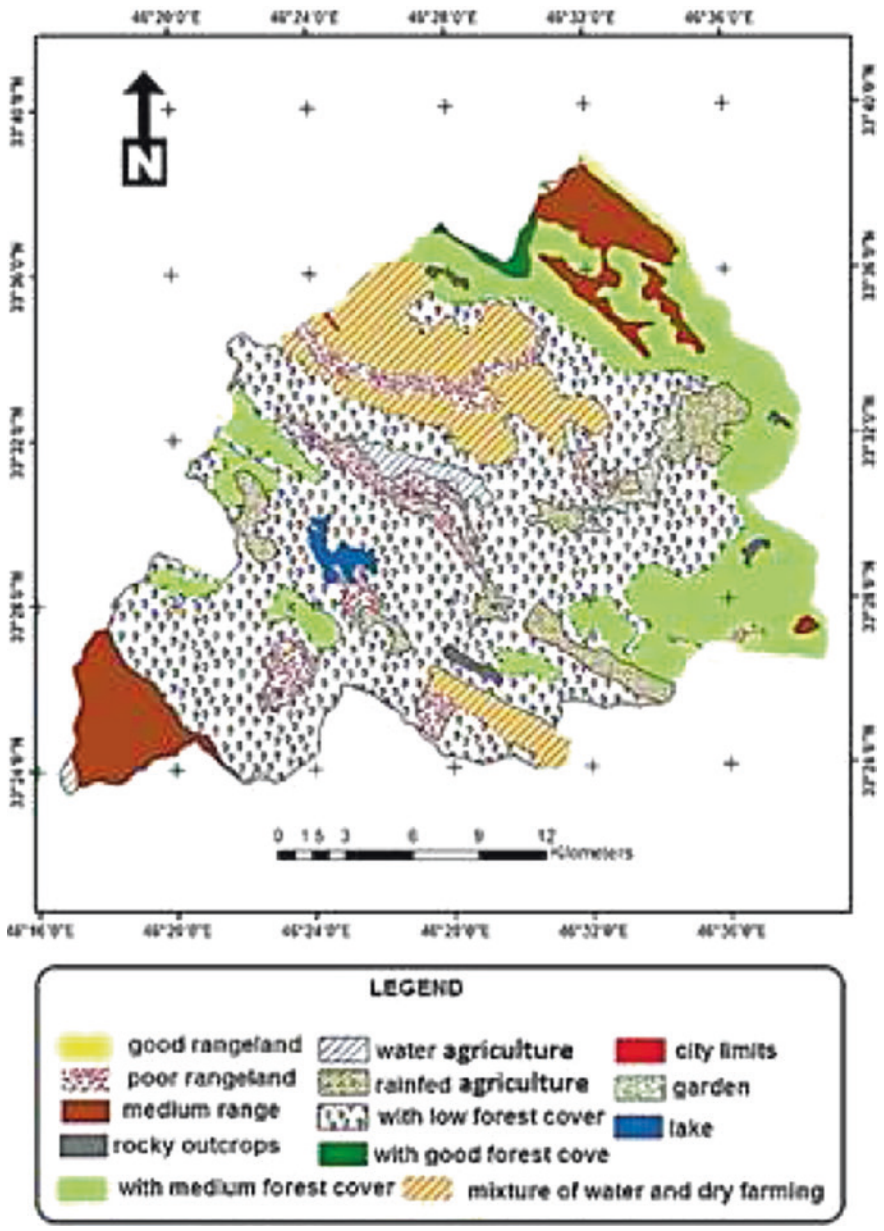


Fig. 2.19 Land use map of Chamgardalan catchment

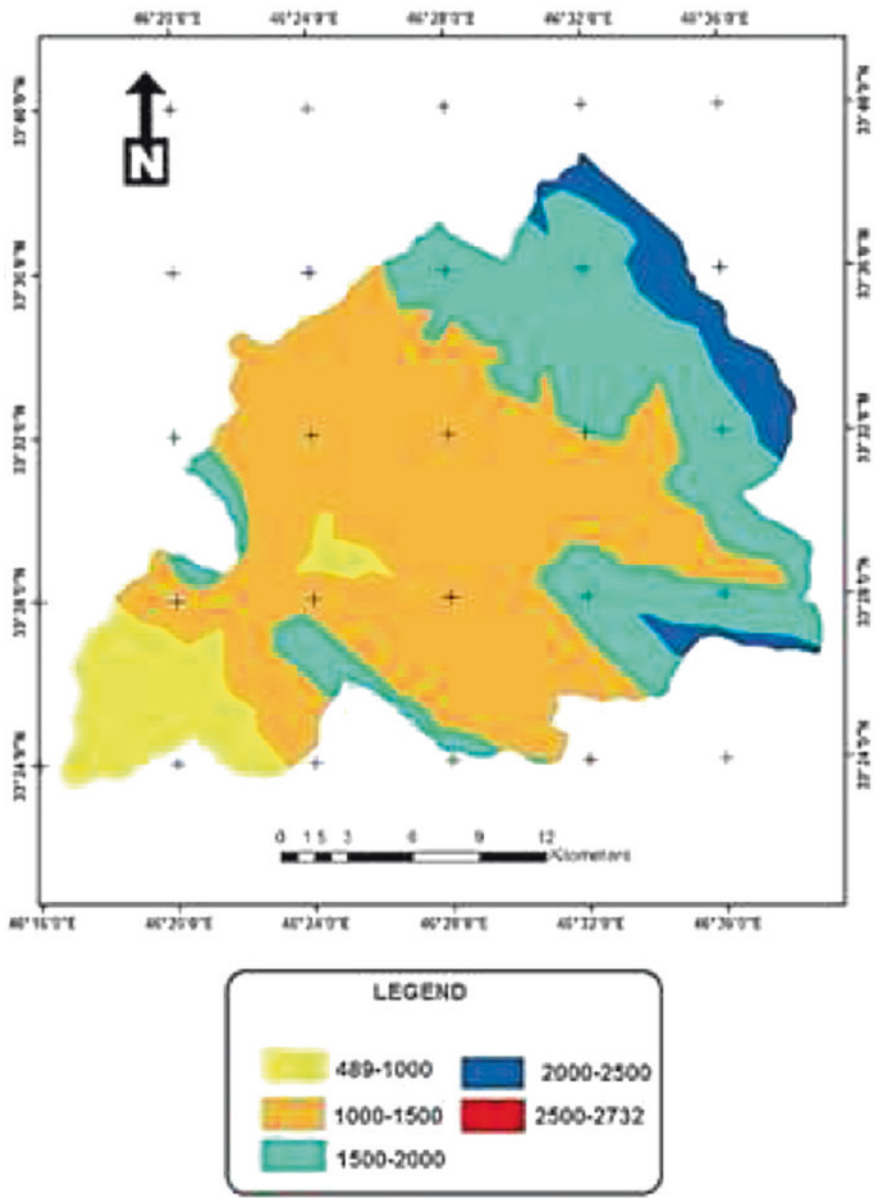


Fig. 2.20 Digital elevation map (DEM) Chamgardalan catchment

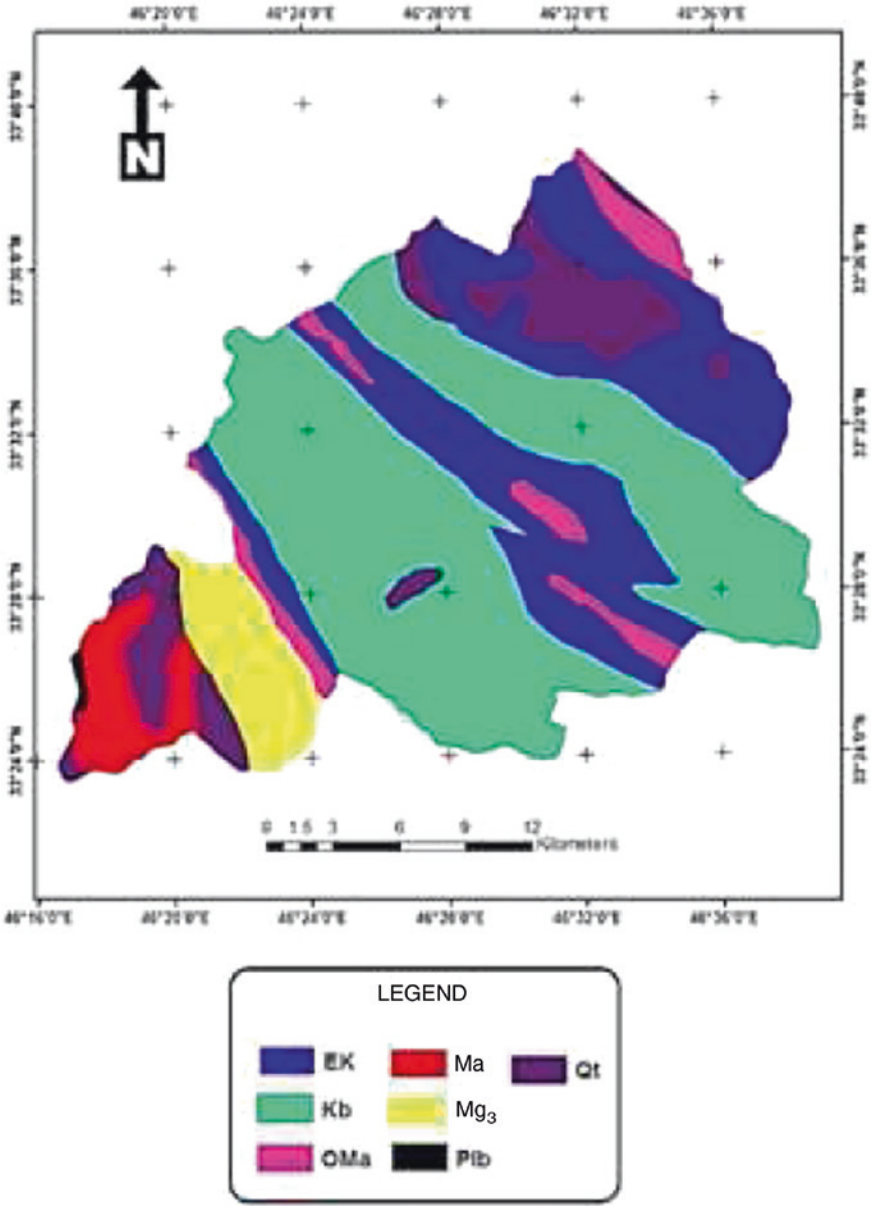


Fig. 2.21 Geology map of Chamgardalan catchment

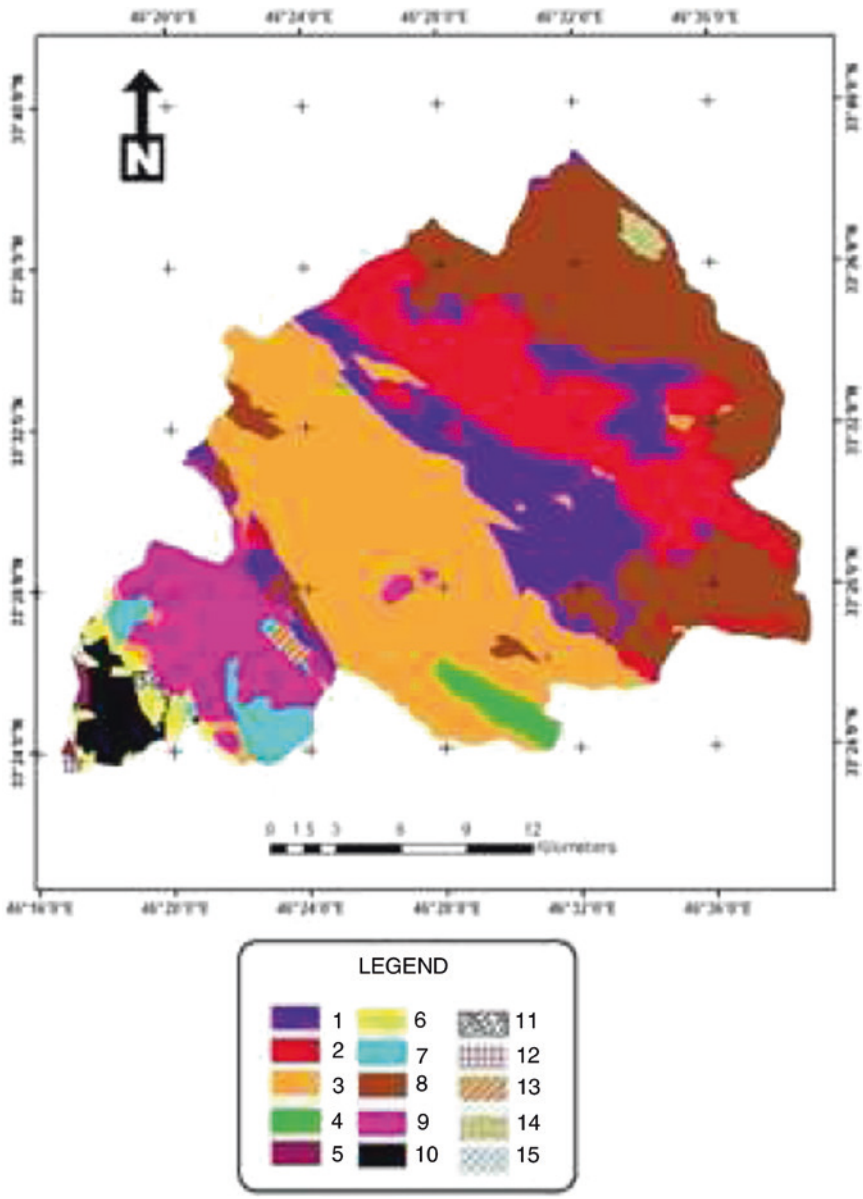


Fig. 2.22 Homogenous units map of Chamgardalan catchment

EPM (Erosion Potential Method) and field data in GIS software. A grid-based distributed model EPM well-matched with ArcGIS9.3 Geographic Information Systems (GIS), was employed to 583.7 km^2 Upper Ilam Dam River in Ilam province. Model considerations were derivatives of digital elevation model (DEM), land use and soil type map of the basin. These considerations and the obtained regular climatological data (1998–2010) were applied (1) to examine the presentation of the EPM model in order to assess the entire sediment yield, (2) to classify various erosion modules. The conclusions shows that observed overall sediment was 22.60 t h^{-1} $year^{-1}$, while the overall estimated sediment concentration using model was 19.97 t h^{-1} $year^{-1}$. The predicted concentration of overall sediment was close to the observed concentration in the stations at basin outlet. Erosion Potential Method (EPM) can be developed for other homogeneous units which don't contain hydrological stations, as the erosion modeling and watershed controlling practices cost lesser than constructing and establishing hydrological stations (Gharibreza et al. 2013b).

2.2.4 Shar-Chi Catchment

The Shar-chi catchment is in the north-western part of Iran and in west Azarbyjan province positioned between the 37° 19′ 34″ to 37° 31′ 29″ east latitude and 44° 34′ 02″ to 45° 00′ 50″ north latitude and its size is 413.9 km^2. Almost 88 % of catchment comprises of hills and mountains and remaining 12 % lies in gentle slope. Impact of land use changes on suspended sediment yield in Shar-chi catchment was predicted on the basis of data available for the duration of 1974–1999. Figure 2.23 is demonstrating the process of sediment generation in Shar-chi catchment.

The major issue regarding this catchment is transformation of rangelands into rainfed crops in hilly areas with lack of management practices. This contributes to maximum erosion for the reason that a large proportion of the fields are positioned on steep slopes and the ploughing is done in the direction of the slope.

So as to identify the land use changes of these regions two unlike Landsat image (ETM, June, 2000 and TM, Aug, 1990), an ASTER image (24.July, 2000) and aerial photographs (1956) were applied. A correlation between release and the

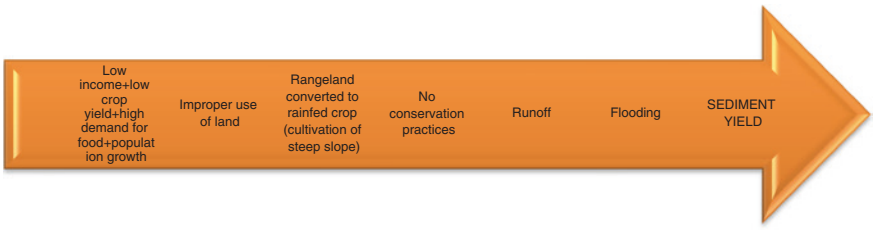


Fig. 2.23 Process of the generated sediment yield in Shar-chi catchment

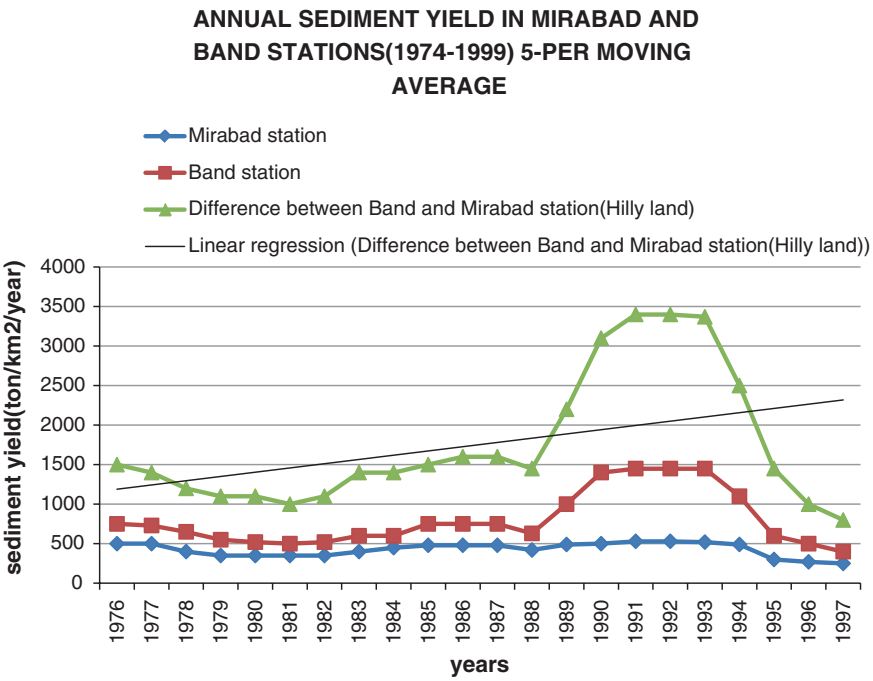
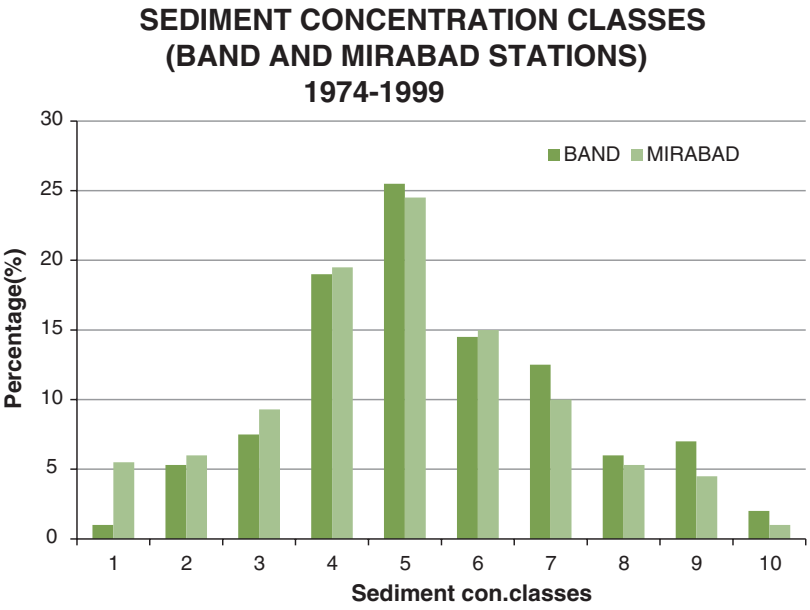


Fig. 2.24 Yearly sediment yields in Mirabad and Band stations and mountainous region

sediment carriage was finally applied. In the case of less release the mean values of the sediment amounts were used, however for the excessive release an exponential function.

Generally, the land use variations occur in the lower part of the catchment, named the Hills, and the impact on the sediment yield was investigated by deducting the sediment yield of the upstream station (Mirabad) from the downstream station (Band). The assessed yearly sediment yield variations of the Hills ranged from 390 to 6529 ton km^2 year^{-1} between 1989 and 1996 the yields ranged from 14,446 to 1298 ton km^2 year^{-1} then during the dry periods from 1997 to 1999 the obtained yields were 390 ton km^2 year^{-1} (Fig. 2.24). A trend line shows that from the period of 1974–1999 there was an upsurge in the sediment yield from the hills, while no such tendency was observed for the upper catchment. Therefore, in the later case amount of sediment yield was taken as a control value due to absence of land use maintenance (Fig. 2.25).

The large amount of sediment yield from the Hills is the evidence of a thoughtful environmental issue, which has resulted in deserting of various lands as well as disturbs the sedimentation in the recently constructed reservoir and in the Lake Uromich wetland. Potential strategies should be implemented for soil maintenance and restrain farming of the land with steep slopes.



Class	Sediment concentration(mg/litr)
1	0-10
2	10-20
3	20-30
4	30-50
5	60-100
6	100-200
7	200-500
8	600-1000
9	1000-50000
10	>50000

Fig. 2.25 Percentage of sediment concentration classes in Band and Mirabad stations

The division of sediment data into ten classes histogram designed for the frequency analysis of data which is represented by Fig. 2.25. For the less quantities, up to 50 mg L^{-1}, the upper Mirabad station has rather large quantities than that of the lower Band station and vice versa. This proves the extremely erosive nature of the soils and less vegetated cover in the Hills, compared to Mountain unit. The overall and average yearly sediment yields for Band station were 20,172 and 776 ton km^{-2} $year^{-1}$, respectively throughout the period from 1974 to 1999, conversely it was 10,829 and 417 ton km^{-2} $year^{-1}$ for Mirabad station (Gharibreza et al. 2013c).

References

Ardakanian R (2005) Overview of water management in Iran. The National Academies press, Washington, DC

Ashraf MA, Ahmad M, Aqib S, Balkhair KS, Bakar NKA (2014) Chemical species of metallic elements in the aquatic environment of an ex-mining catchment. Water Environ Res 86(8):77–728

Bakar AFA, Yusoff I, Ng TF, Ashraf MA (2015) Cumulative impacts of dissolved ionic metals on the chemical characteristics of river water affected by alkaline mine drainage from the Kuala Lipis gold mine, Pahang, Malaysia. Chem Ecol 31(1):22–33. doi:10.1080/02757540.2014.950569

Evans R (1980) Mechanics of water erosion and their spatial and temporal controls: an empirical viewpoint. In: Kirkby MJ, Morgan RPC (eds) Soil erosion. Wiley, Chichester, pp 109–128

FAO Water Reports (Food and Agriculture Organization) (2008) Irrigation in middle east region in Figure AQUASTAT Survey—2008

Ghaffari G, Keesstra S, Ghodous J, Ahmadi H (2009) SWAT-simulated hydrological impact of land-use change in the Zanjanrood basin, Northwest Iran. Hydrol Process 24(7):892–903

Gharibreza M, Raj JK, Yusoff I, Ashraf MA, Othman Z, Zakaria W, Tahir WM (2013a) Effects of agricultural projects on nutrient levels in Lake Bera (Tasek Bera). Peninsular Malaysia. Agric Ecosyst Environ 165(1):19–27

Gharibreza M, Raj JK, Yusoff I, Othman Z, Zakaria W, Tahir WM, Ashraf MA (2013b) Historical variations of Bera Lake (Malaysia) sediments geochemistry using radioisotopes and sediment quality indices. J Radioanal Nuclear Chem 295(3):1715–1730

Gharibreza M, Raj JK, Yusoff I (2013c) Sedimentation rates in Bera Lake (Peninsular Malaysia) using 210Pb and 137Cs radioisotopes. Geosciences J 17(2):211–220. doi:10.1007/s12303-013-0013-3

Gharibreza M, Raj JK, Yusoff I, Othman Z, Zakaria W, Tahir WM, Ashraf MA (2013d) Land use changes and soil redistribution estimation using 137Cs in the tropical Bera Lake catchment. Malaysia. Soil Till Res 131(1):1–10

Gharibreza M, Habibi A, Imamjomeh SR, Ashraf MA (2014) Coastal processes and sedimentary facies in the Zohreh River Delta (Northern Persian Gulf). CATENA 122(1):150–158. doi:10.1016/j.catena.2014.06.010

Haregeweyn N, Poesen J, Nyssen J, Verstraeten G, de Vente J, Govers G, Deckers S, Moeyersons J (2005) Specific sediment yield in Tigray-Northern Ethiopia: assessment and semi-quantitative modeling. Geomorphology 69:315–331

Kabir A, Bahremand A (2011) Water balance of Gorganrood river basin East of Iran. Afr J Agric Res 6(25):5591–5599

Mahmoudi B, Bakhtiari F, Hamidifar M, Danehkar A (2010) Effects of land use change and erosion on physical and chemical properties of water (Karkhe Watershed). Int J Environ Res 4(2):217–228

Masih I, Ahmad M, Uhlenbrook S, Turral H, Karimi P (2009) Analysing streamflow variability and water allocation for sustainable management of water resources in the semi-arid Karkheh river basin, Iran. Phys Chem Earth Parts A/B/C 34(4–5):329–340

Morgan RPC (1986) Soil erosion and conservation. Longman Scientific and Technical, Wiley, New York

Natural Resources and Watershed Management Organization (2011)

Nyssen J, Mitiku H, Moeyersons J, Poesen J, Deckers J (2001) Removal of rock fragments and its effect on soil loss and crop yield. Soil Use Manag 17:179–187

Poesen J, Torri D, Bunte K (1994) Effects of rock fragments on soil erosion by water at different spatial scales: a review. Catena 23:141–166

PSIAC (1968) Report of the water management subcommittee on sectors affecting sediment yield in the pacific southwest area and selection and evaluation of measures for reduction of erosion and sediment yield. ASCE, 98, report no. HY12

Sarmadian F, Rahimy P, Keshavarzi A (2010) Modeling of sediment yield and bicarbonate concentration in Kordan Watershed. Iran J Agric Sci Technol 12:121–131

Sima S, Tajrishy M (2013) Using satellite data to extract volume–area–elevation relationships for Urmia Lake, Iran J Great Lakes Res 39:90–99

UNEP United Nation Environmental Program/Global Resource Information Database/The Drying of Iran's Lake Urmia and its Environmental Consequences (2012)

USDA-SCS (1964) Hydrology. Section 4 part I, catchment planning. National engineering handbook. US department of agriculture, Soil conservation service, Washington, DC

Zulkifley MTM, Ng TF, Raj JK, Hashim R, Ashraf MA (2014) The effects of lateral variation in vegetation and basin dome shape on a tropical lowland stabilization in the Kota Samarahan-Asajaya area, West Sarawak, Malaysia. Acta Geol Sin-Eng 88(3):894–914

http://www.springer.com/978-4-431-55563-6

Application of the SWAT Model for Water Components Separation in Iran

Hosseini, M.; Ashraf, M.A.

2015, X, 105 p. 85 illus., 55 illus. in color., Hardcover
ISBN: 978-4-431-55563-6