IMPACT OF LANDUSE CHANGE ON WATER AND LAND PRODUCTIVITY IN KARKHEH RIVER BASIN-IRAN

IMPACT DU CHANGEMENT DE L'UTILISATION DES TERRES SUR LA PRODUCTIVITE DE L'EAU ET DE LA TERRE DANS LE BASSIN FLUVIAL DE KARKHEH, IRAN

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ABSTRACT

As water resources become further stressed due to increasing levels of societal demand, understanding the effect of climate change on various components of the water cycle is of strategic importance in management of this essential resource. The Karkhe River Basin (KRB) is located in the south western part of Iran, with geographical coordinates between 30° to 35° N latitude and 46° to 49° E longitude with total area of about 50800 km^2. The basin supports important agricultural activities over huge rainfed areas and lands under traditional and modern irrigation systems. Nearly two thirds of the basin lies in the mountains (elevations between 1000 and 2500 m), and surface and groundwater resources are replenished from winter snow falls in the high Zagros ranges. River becomes progressively more saline as it flows downstream of the newly constructed Karkheh dam with electrical conductivities exceeding 3dS/m. The basin has a mean annual runoff of 5.1 km^3 and a mean annual ground water recharge of 3.4 km^3. Population growth has negative influence on land use changes, and has put pressure on the water resources and productivity in KRB during the last few decades.

This study investigates and compares different land use trends over past two decades (1975 to 2002). It also quantifies the impact of possible climate change on the water resources of the KRB and explores various strategies based on considering IWRM (Integrated Water Resource Management).

The SWAT (Soil and Water Assessment Tools) model generates scenarios under alternative

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conditions (e.g. climate change, vegetation, land use etc). The model has been set up using the data on terrain, land use, soil type and meteorological conditions. The model has been calibrated using land use conditions pertaining to 1980's to 2000's and using daily-river discharges. The model was then applied to analyze the effect of changing land use from 1975 to 2002.

Key words: *Water resource, Land use, SWAT model, Water and land productivity.*

RESUME

Les ressources en eau deviennent rares en raison de l'augmentation de la demande sociale. Il est nécessaire de comprendre les effets du changement climatique sur les différentes composantes du cycle de l'eau pour la gestion de cette ressource essentielle. Le bassin fluvial de Karkheh (KRB) est situé au sud-ouest de l'Iran, à latitude N de 30 ° à 35 ° et à longitude E et 46 ° à 49 ° ayant une superficie totale d'environ 50800 km2. Le bassin soutient les activités agricoles d'une grande superficie irriguée par les pluies dans le cadre des systèmes d'irrigation traditionnel et moderne. Environ deux tiers de la superficie du bassin se trouve dans les montagnes (altitudes entre 1000 et 2500 m). Les ressources en eau de surface et souterrainne reçoivent l'eau des chutes de neige hivernales de la haute chaîne de Zagros. La rivième devient de plus en plus salée quand elle coule vers le nouveau barrage de Karkheh en aval avec des conductivités électriques qui dépassant 3ds / m. Le bassin a un écoulement annuel moyen de 5,1 km^3 et une recharge d'eau souterraine moyenne annuelle de 3,4 km^3. Au cours des dernières décennies, la croissance démographique avait un impact négatif sur les changements de l''utilisation des terres, et a mis la pression sur les ressources en eau et la productivité du KRB.

Cette étude examine et compare les différentes tendances d'utilisation des terres au cours des deux dernières décennies (1975 à 2002). Elle quantifie également l'impact possible des changements climatiques sur les ressources en eau du KRB, et explore différentes stratégies de la GIRE (Gestion Intégrée des Ressources en Eau).

Le modèle SWAT (Outils d'évaluation du sol et de l'eau) produit des scénarios dans les conditions alternatives (les changements climatiques, la végétation, l'utilisation des terres, etc). Le modèle a été mis en place en utilisant les données sur le terrain, l'utilisation des terres, le type du sol et les conditions météorologiques. Le modèle a été calibré en utilisant les conditions d'utilisation des terres des années 1980 à 2000 ainsi que le débit quotidien de la rivière. Le modèle a ensuite été appliqué pour analyser l'effet du changement d'utilisation des terres depuis 1975 à 2002.

Mots clés: *Ressources en eau, utilisation des terres, modèle SWAT, productivité de l'eau et de la terre.*

1. INTRODUCTION

The impact of climate change presents extraordinary challenges for users and managers of water resources. This is particularly true in basins that are already facing water scarcity. Water scarcity is particularly acute in many developing countries, which have to cope with rapidly expanding populations, and the need to eradicate poverty and improve people's quality of life. Water scarcity is also a common problem in many parts of the world, especially the dry areas. Per-capita share is rapidly dropping below the scarcity level of 1000m^3 annual as population grows rapidly and water diverted from agriculture to higher priority sectors. At the same time poor developing countries are seeking to achieve some level of food security by changing the land use to increase the area for food production. Water use is currently optimized through maximizing yield per unit area, a sound strategy when agricultural land area is limiting. However, in water scare areas, it is water, not land that is more limiting and maximizing productivity per unit of water consumed is more important.

Increase in population causes more pressure on lands for expanding arable lands and converting forest and rangelands to dry farming (rainfed farming). Also, overgrazing causes land degradation and converts good rangelands to poor rangelands and sometimes bare lands. Development and growth in urban and industrial area means decrease in natural resources (land, water and natural vegetation cover).

Over the past three decades, increasing access to water (mainly groundwater) has turned large rainfed areas into irrigated areas. Farm mechanization and increased use of subsidized fertilizer have resulted in a remarkable recovery of crop yields. Wheat yields in the upper KRB increased from 1500 kg/ha in 1970 to over 5000 kg/ha in 2004. Similarly, wheat yields in the lower KRB jumped from a mere 1000 kg/ha to over 4000 kg/ha during the same period. However, these yields are still lower than the other regions of Iran. Irrigation efficiencies are as low as 35% (Keshavarz et al., 2003). The amount of water applied to irrigate field crops is almost double what is actually required. As a result, productivity of water is very low, i.e. 0.5 kg/m^3 for most of the field crops.

2. KARKHEH RIVER BASIN (KRB) AND LAND USE

The Karkhe River Basin (KRB) is located in the south western part of Iran, between 30° to 35° N latitude and 46° to 49° E longitudes with total area of about 50800 km^2. The basin supports important agricultural activities, in huge rainfed areas and area under traditional and modern irrigation systems. Nearly two thirds of the basin lies in the mountains (elevations between 1000 and 2500 m), and surface and ground water resources are replenished from winter snow falls in the high Zagros ranges. River becomes progressively more saline as it flows downstream of the newly constructed Karkheh dam with electrical conductivities exceeding 3dS/m. The basin has a mean annual runoff of 5.1 km^3 and a mean annual ground water recharge of 3.4 km^3. Population growth has negative influence on land use changes, and has put pressure on the water resources and productivity in KRB during the last few decades.

According to existing reports and records, field surveys and interviews with local communities and local experts, there has been a vast change in land use of KRB, particularly in natural vegetation cover. For studying this issue and investigating on these changes and predicting its consequences, remote sensing techniques (satellite images) and GIS capabilities are very powerful and useful tools.

The oldest images which exist for Iran (and KRB) is Landsat MSS data of 1975 and the latest images are Landsat ETM$^+$ image of 2002. Table 1 shows the area coverage of different land use types in KRB which is extracted from 2002 images and Table 2 shows the same for the 1975 images, by using supervised classification technique and field check (Mirghasemi et al, 2006).

Table1. Area coverage of different land use types in KRB based on Landsat ETM$^+$ image of 2002 (Ha)

Afforestation	**Bare Lands**	**Dry Farming**	**Follow**
156.25	12821.93	681822.18	15736.35
Good Forest Canopy Cover	Good Range Canopy Cover	Irrigated Farming or Orchard	Mix of Irrigated & Dry Farming
17349.66	241056.78	201980.19	872148.66
Moderate Forest Canopy Cover	Moderate Range Canopy Cover	Poor Forest Canopy Cover	Poor Range Canopy Cover
560324.31	806432.24	475132.49	243318.28
Urban	Water Body	Wet Land	
34714.899	11281.859	476.32	

Table2. Area coverage of different land use types in KRB based on Landsat MSS data of 1975 (Ha)

Dry Farming	**Dry+Irrigated Farming**	**Forest**
247057.58	403861.43	922066.14
Irrigated Farming	MSS Data GAP	Poor Range
557695.31	613.92	460533.60
Range	Scattered Dry Farming	Urban Area
777785.56	802668.44	2470.41

Comparing land use map extracted from 1975 and 2002 images one notices about 50% increase in irrigated farming lands and 100% increase in dry farming lands (it means converting rangelands and under story of forest lands to farm lands). Degradation in forest lands is mostly in the form of forest generation (Replacing generation by seed with sprouting) and its canopy cover but about 25% decrease in forest cover has happened. This study is aimed to investigate and compare different land use trends over past two decades (1975 to 2002). The study also quantifies the impact of possible land use change on the water resources of the KRB and explores various strategies based on considering IWRM (Integrated Water Resource Management: Figure 1).

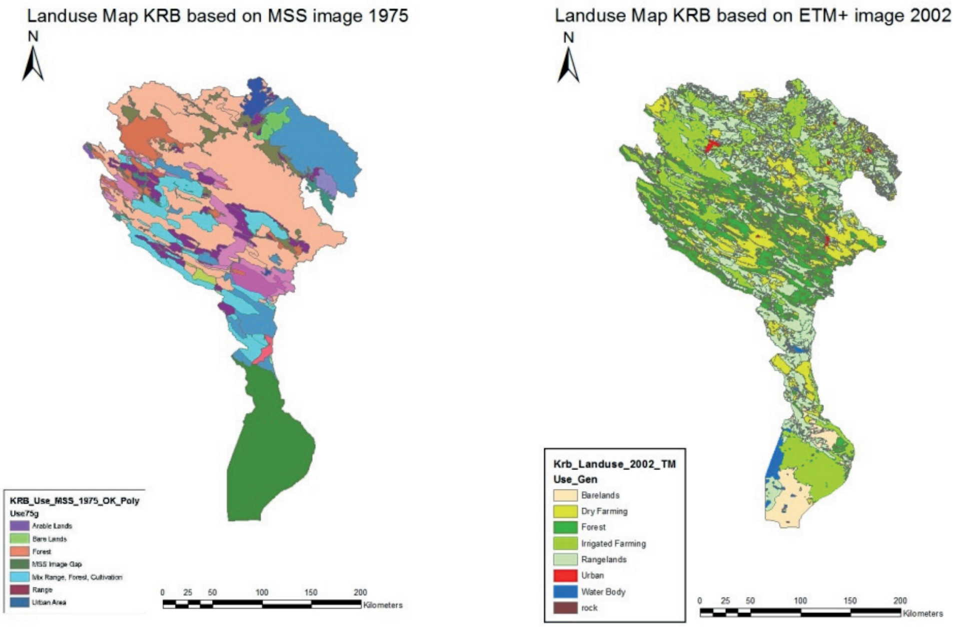


Fig.1. Landuse maps based on MSS image (1975) and ETM+ (2002)

3. SWAT SET UP MODEL

The Soil and Water Assessment Tool (SWAT) is a process-based continuous hydrological model and the main components of the model include: climate, hydrology, erosion, soil temperature, plant growth, nutrients, pesticides, land management, channel and reservoir routing. The public domain model ArcSWAT2009 working with the ArcGIS9.3 interface was selected for this study.

The model divides the watershed into multiple sub-basins (in KRB 258 sub-basin), which are then further sub-divided into hydrological response units (HRUs) which consist of homogeneous land use, management and soil characteristics. SWAT divides rainfall into different components which include evaporation, surface runoff, infiltration, plant uptake, lateral flow and groundwater recharge. Surface runoff from daily rainfall is estimated with a modification of the SCS curve number method from the United States Department of Agriculture Soil Conservation Service (USDA SCS) and peak runoff rates using a modified rational method (Neitsch et al., 2005). The model estimates plant growth under optimal conditions, and then computes the actual growth under stresses inferred by water and nutrient deficiency. Detailed descriptions of the model can be found in Arnold et al. (1998), Srinivasan et al. (1998), Gassman et al. (2007) and Williams et al. (2008). SWAT requires three basic files for delineating the basin into sub-basins and HRUs: a digital elevation model (DEM), soil map (was obtained from the global soil map of the Food and Agriculture Organization of the United Nations (FAO)) and land use/land cover (LULC) map. For analyzing the impact of land use change we used, two land use maps belong different time (1975 and 2002). Both of them were obtain by image processing method. First one is based on Landsat ETM+ image of 2002 and the second one, based on Landsat MSS data of 1975. Figure 2, shows the running of SWAT model in Arc-GIS interface based on 2002 landuse map.

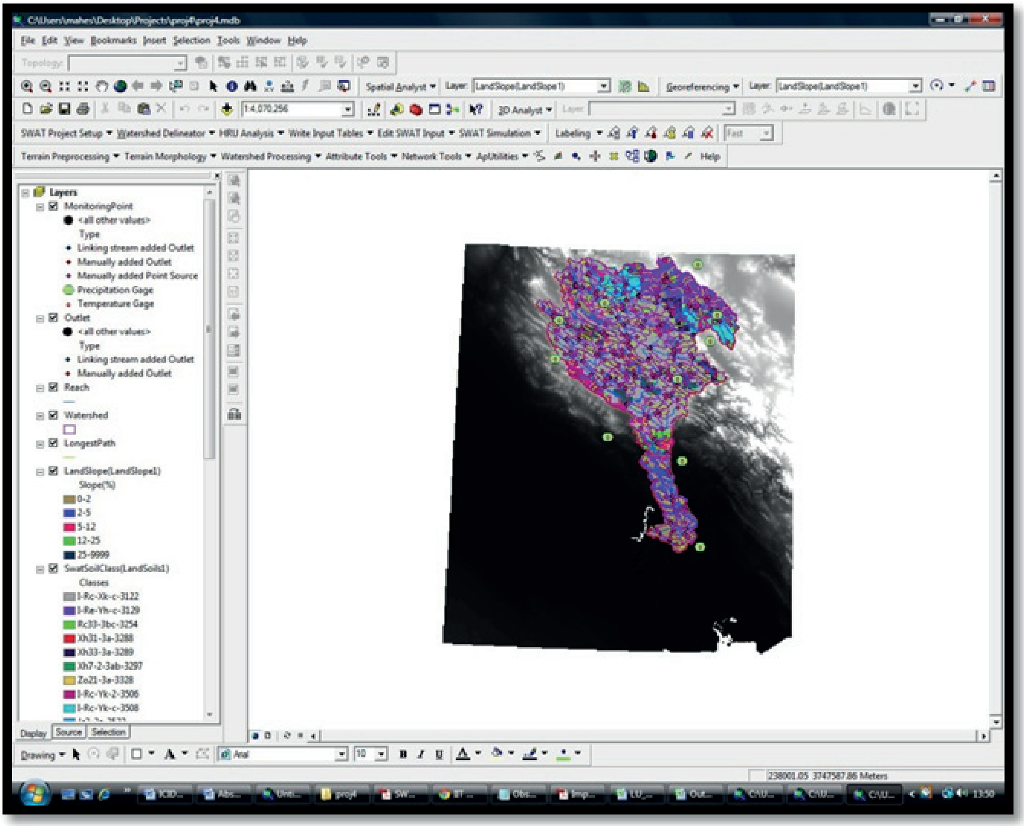
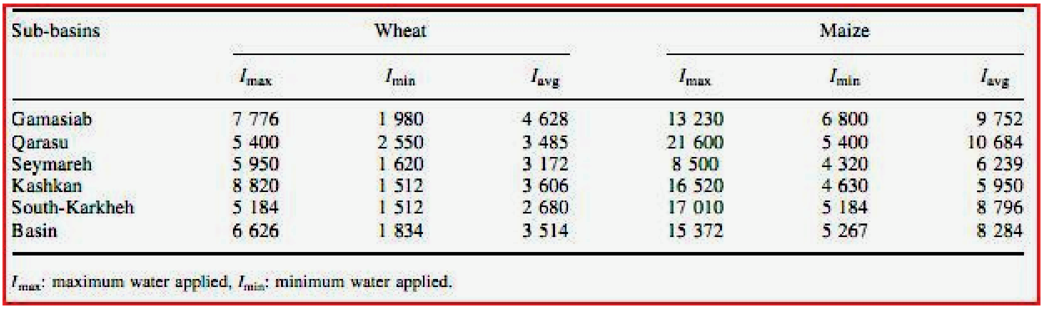


Fig. 2. KRB modeled based on ETM+ (2002) in Arc-GIS by SWAT model

4. WATER AND LAND PRODUCTIVITY IN KRB

The situation in the KRB is not much different from other parts of the world where about 93% of the total withdrawals are diverted to meet agricultural requirements. In the absence of sufficient surface water resources, groundwater use in the basin has increased many folds over the last two decades. The future of irrigated agriculture, which produces more than 60% of total grain production, is threatened by low crop yields, low water use efficiencies and increasing salinity and water logging problems. (T. OWEIS et al.1999). In the KRB irrigation schedules vary a lot. The field measurements indicate that farmers having access to groundwater tend to apply more water for irrigation than those who are fully dependent on surface water. Farmers located in the upper part of the KRB use more groundwater as the quality of pumped water is suitable for irrigation. Farmers do not usually plan their irrigations in advance. Their decision mainly depends upon visual plant stress and accessibility to surface water and groundwater resources. Data collected in the field show large differences in the amounts of water applied for irrigation to wheat and maize in different sub-basins of the KRB (Table 3). The average amount of water applied to wheat and maize is 3514 and 8284 m^3/ha, respectively. The large gap between maximum and minimum values shows that farmers do not plan their irrigations according to crop water requirements. These findings are in agreement with the observations of Keshavarz et al. (2003). They have reported irrigation water applications of over 6000 m^3/ha for wheat and 10 000 –13 000 m^3/ha for maize. These water application rates are also higher than the net irrigation requirements (crop water requirement – effective rainfall) recommended by the Ministry of Jihad-e-Agriculture. They have recommended 2600 m^3/ha for wheat and 5900 m^3/ha for maize, respectively (Ministry of Jihad-e-Agriculture, 1998). This is a clear demonstration of the fact that irrigation amounts applied by farmers have no relevance to actual crop water requirements. They usually tend to maximize their crop yields through excessive irrigation. However, in most cases irrigation water is applied at less water-sensitive stages of the growth cycle, causing significant losses through evaporation and deep percolation thereby reducing the efficiency of water use.

Table 3. Irrigation water applied to wheat and maize (m^3/ha) in the KRB (Qureshi et al. 2009)



Sub-basins	Wheat			Maize		
	I_{max}	I_{min}	I_{avg}	I_{max}	I_{min}	I_{avg}
Gamasiab	7 776	1 980	4 628	13 230	6 800	9 752
Qarasu	5 400	2 550	3 485	21 600	5 400	10 684
Seymareh	5 950	1 620	3 172	8 500	4 320	6 239
Kashkan	8 820	1 512	3 606	16 520	4 630	5 950
South-Karkheh	5 184	1 512	2 680	17 010	5 184	8 796
Basin	6 626	1 834	3 514	15 372	5 267	8 284

I_{max}: maximum water applied, I_{min}: minimum water applied.

5. RESULTS AND RECOMMENDATION

SWAT calculates the Surface Water, ground water and water yield at HRU (hydrological response unit) and sub-basin levels on a daily/monthly timescale. The above parameters results of the KRB from 1982 to 2002 calculated. But for getting the results and better ability for comparing, we chose only the first month (January) 2002 just for showing. Figure 2 presented the comparison of the surface water, ground water and water yield for January 2002. Based on the analyzing the output of SWAT model, average surface runoff by changing the land use from 1975 condition to 2002, is increased 16%. Ground water and water yield decreased around 18% in same condition. By changing just the land use, and keeping other condition as no change in climate condition, no change in any management methods and many other things, we saw the surface runoff increased, the ground water amount and water yield decreased. Table 4 had been show the three selected entities for three randomly selected sub-basins located in upper (sub-basin no.23), middle (sub-basin no.225) and lower part (sub-basin no.256) of the KRB.

Farmers in the KRB are found to be ignorant of actual crop water requirements and tend to over-irrigate their lands. As plants are constrained in their capacity to extract more water than the atmospheric demand, extra water is lost as evaporation. Therefore, farmers need to be educated about the actual irrigation requirements for different crops. By practicing improved irrigation schedules, deep percolation losses can be significantly reduced. This is especially needed in south-Karkheh where the groundwater is shallow and saline and any water lost through deep percolation cannot be reused.

Improved irrigation techniques will reduce the groundwater significantly, which will reduce the production costs and increase net farm income of farmers. The saved water can be used to bring more area under irrigated cultivation. Out of 1.06 million ha potential irrigated area, only 378 000 ha are currently being cultivated due to shortage of water. Therefore saving irrigation water would be of great importance for increasing the irrigated area and improving agricultural production in the country.

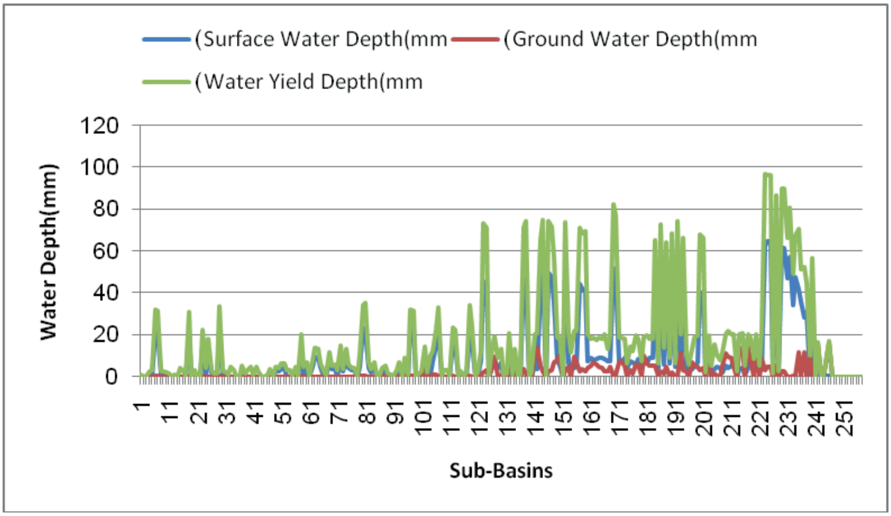


Fig. 2 (a). Range of Surface water, Ground water and water yield for January 2002 based on land use map of 1975

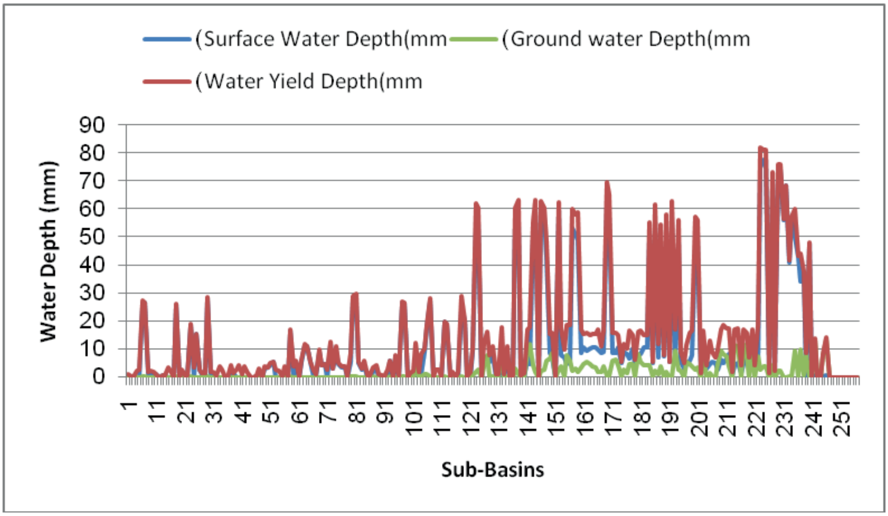


Fig. 2 (b). Range of Surface water, Ground water and water yield for January 2002 based on land use map of 2002

Table 4. Differences between LU1975 and LU2002 in three sub-basins chosen randomly in upper, middle and down part of KRB

Sub_ basin	Month	LU-1975			LU-2002			Location
		SUR Qmm	GW_ Qmm	WYL Dmm	SUR Qmm	GW_ Qmm	WYL Dmm	
23	1	15.58956	0.2748	22.50378	18.559	0.229	19.071	Upper-KRB
225		64.96476	4.7712	95.97294	77.339	3.976	81.333	Middle-KRB
256		0.00084	0.0096	0.01298	0.001	0.008	0.011	Down-KRB
23	2	8.93256	1.7004	14.48922	10.634	1.417	12.279	Upper-KRB
225		1.50696	24.744	26.47212	1.794	20.62	22.434	Middle-KRB
256		0	0.006	0.00826	0	0.005	0.007	Down-KRB
23	3	10.87128	6.5112	22.02352	12.942	5.426	18.664	Upper-KRB
225		7.22736	24.4056	34.17752	8.604	20.338	28.964	Middle-KRB
256		0	0.0036	0.0059	0	0.003	0.005	Down-KRB
23	4	35.25816	17.4024	67.1479	41.974	14.502	56.905	Upper-KRB
225		0	11.8032	11.63008	0	9.836	9.856	Middle-KRB
256		0	0.0012	0.00354	0	0.001	0.003	Down-KRB
23	5	0	23.9928	23.96934	0	19.994	20.313	Upper-KRB
225		0	2.8404	2.81548	0	2.367	2.386	Middle-KRB
256		0	0.0012	0.00236	0	0.001	0.002	Down-KRB
23	6	0	10.728	10.7321	0	8.94	9.095	Upper-KRB
225		0	1.0248	1.02896	0	0.854	0.872	Middle-KRB
256		0	0	0.00236	0	0	0.002	Down-KRB
23	7	0	2.7816	2.832	0	2.318	2.4	Upper-KRB
225		0	0.3972	0.40946	0	0.331	0.347	Middle-KRB
256		0	0.3972	0.40946	0	0	0.002	Down-KRB
23	8	0	0.9072	0.90506	0	0.853	0.896	Upper-KRB
225		0	0.1464	0.20296	0	0.122	0.137	Middle-KRB
256		0	0	0.00236	0	0	0.002	Down-KRB
23	9	0	0.3276	0.33276	0	0.308	0.331	Upper-KRB
225		0	0.0528	0.10148	0	0.044	0.057	Middle-KRB
256		0	0	0.00118	0	0	0.002	Down-KRB
23	10	0	0.1404	0.15812	0	0.119	0.135	Upper-KRB
225		0	0.0204	0.0354	0	0.017	0.03	Middle-KRB
256		0	0	0.00236	0	0	0.002	Down-KRB
23	11	0	0.0708	0.19116	0	0.059	0.162	Upper-KRB
225		0	0.0072	0.05192	0	0.006	0.018	Middle-KRB
256		0	0	0.00236	0	0	0.002	Down-KRB
23	12	1.69344	0.072	2.75884	2.016	0.06	2.338	Upper-KRB
225		0.4242	0.06	0.70682	0.504	0.049	0.565	Middle-KRB
256		0	0	0.00236	0	0	0.002	Down-KRB

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