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ARID ECOSYSTEMS

Журнал освещает фундаментальные исследования и результаты прикладных работ по проблемам аридных экосистем и борьбы с антропогенным опустыниванием в региональном и глобальном масштабах. Издается с 1995 года по решению Бюро Отделения общей биологии Российской академии наук.

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Addresses:
*119991, Moscow, Goubkina str., bild. 3, IWP RASN,
Tel.: (499) 135-70-41. Fax: (4995) 135-54-15,
E-mail: novikova@aqua.laser.ru,
mab.ru@relcom.ru

**367025, Makhachkala, Gadjieva str., 45, DSC RASN, PIBR
Tel./ Fax: (872-2) 67-60-66,
E-mail: pibrdncran@iwt.ru

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РОССИЙСКАЯ АКАДЕМИЯ НАУК
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*119991 Москва, ул. Губкина, 3, ИВП РАН, каб. 419
Телефон: (495) 135-70-41, Телефакс: (495) 135-54-15,
E-mail: novikova@aqua.laser.ru
mab.ru@relcom.ru

**367025 Махачкала, ул. Гаджиева. 45
Телефон/Факс: (872-2) 67-60-66,
E-mail: pibrdncran@iwt.ru

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ВВЕДЕНИЕ

О МЕЖДУНАРОДНОМ СОВЕЩАНИИ ПО «АНТРОПОГЕННЫМ АСПЕКТАМ ИЗМЕНЕНИЙ КЛИМАТА И ОКРУЖАЮЩЕЙ СРЕДЫ В ЦЕНТРАЛЬНОЙ АЗИИ»

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Отдел Географии и планирования,
Государственный Университет Грэнд-Вэлли,
1150 Оусейбл Холл, 1 Кампус драйк,
Оллендейл, MI 49401, Мичиган, США

Существует растущее понимание среди ученых, политиков и простых людей во многих странах мира, что местные и региональные аспекты окружающей среды имеют огромное значение в охране природных ресурсов мира. Мы можем перефразировать известное высказывание, которое знали еще в школе «думать глобально, а действовать локально». На самом же деле необходимо думать локально, а действовать глобально. Нельзя забывать о том, что у нас, у всех одна планета и все мы зависим друг от друга в этом очень взаимосвязанном мире. Никто из нас не может чувствовать себя защищенным пока в мире существует самодовлеющее антропогенное воздействие.

Настоящее совещание призвано осветить антропогенные аспекты изменения климата и окружающей среды в регионах Центральной Азии и показать растущее понимание сущности взаимосвязанных процессов глобального и локального масштабов.

Совещание было организовано Государственным Университетом Грэнд Вэлли в мае 2004 года в штате Мичиган США, которое собрало ученых со всего мира для обсуждения критической ситуации в регионе, обмена опытом и результатами исследований, а так же для обсуждения возможного в будущем сотрудничества в целях решения экологического кризиса в Центральной Азии.

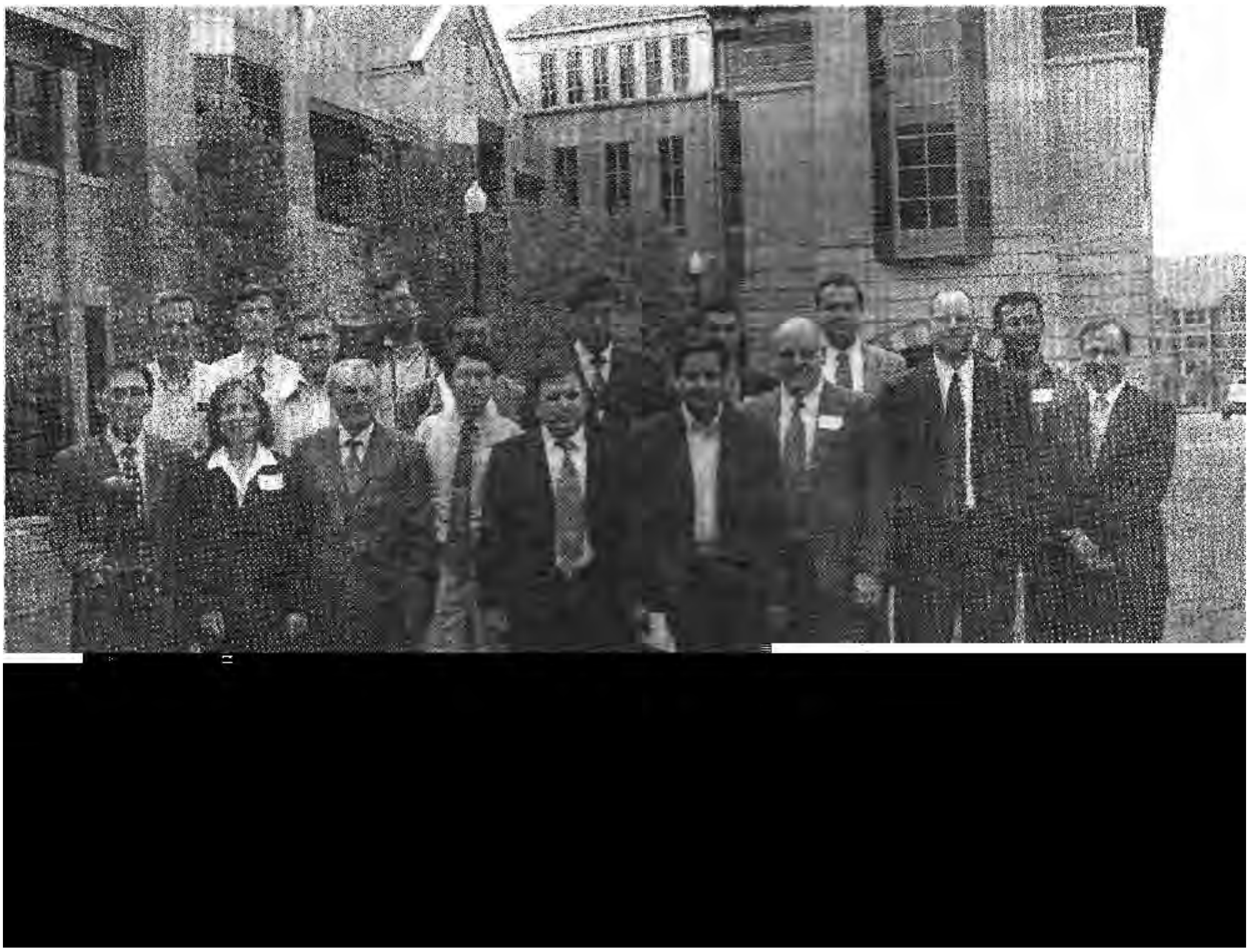
Доклады совещания были разнообразного и междисциплинарного характера, с участием представителей всех стран центральной Азии от Турции до Монголии, от России до Афганистана, из местного Университета Мичиган (США), Московского Госуниверситета (Россия), Прикаспийского института биологических ресурсов ДНЦ РАН (Россия), Института атомной физики национального научного центра Казахстана, Гидрометеорологического института Узбекистана, Самаркандского университета, Университета Бен-Гурион (Израиль), Университета штата Небраска (США), Университета штата Индиана (США), Штутгартского Университета (Германия). Ключевыми докладчиками конференции выступили заслуженный профессор доктор Филип Миклин, из географического факультета Мичиганского Университета, доктор Герман Куст заместитель директора Института почвоведения РАН, МГУ и другие признанные специалисты из Центральной Азии.

За круглым столом ученые со всего мира обменивались мнениями, делились своими открытиями, идеями, заботами и планами на будущее стран Центральной Азии. Было принято общее соглашение участников, где отмечена необходимость привлечения внимания мирового сообщества для решения предстоящих вопросов на локальном и региональном уровнях.

Мы очень рады и гордимся тем, что выбор лучших докладов представленных на конференции, осуществлен нами для публикации в Международном журнале «Аридные экосистемы». Хотелось бы поблагодарить всех ученых, без помощи которых мы не смогли бы организовать конференцию и издать специальный номер журнала «Аридные экосистемы»:

Кин М. Ма, Рой Коул, Уэнди Уэннер, Присцилла Кимбоко, Эрика Кинг, Гейл Девис, Валерий Неронов, Майкл Глянц, Залибек Залибеков, Нина Новикова, Филип Миклин, Герман Куст, Рашид Кулматов, Леон Палмер, Джой Кэли, Синди Зенер, Артем Ермилов, а так же Факультет

Государственного университета Грэнд Вэлли, а лице преподавателей и студентов, которые работали со мной над проектом. Елена Любимцева, Председатель Организационного комитета Первого международного совещания «Антропогенные аспекты изменений климата и окружающей среды *в* Центральной Азии».



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третий ряд: Артем Ермилов, Герман Куст.
Participants of the First International Workshop on the Human Dimensions of Climate and Environmental Change in Central Asia.
Row 1 left to right: Dr. Djavdat Nurbatv, Dr. Elena Lioubimtseva (Conference Chair), Dr. Zalibek Zalibekov, Mr. Kin Ma, Dr. Etem Karakaya, Dr. Muhtor Nasyrov, Dr. Melvin Northup. Mr. Neil Bestman, Dr. Roy Cofe;
Row *2* left to right: Or. Philip Micklin, Mr, Dilyor Kayumov, Dr. Rafique Keshavjee, Dr. Rash id Kulmatov, Mr. Kuatbay Bektemirov, Mr. Luke Potoski, Dr. Yunden Bayarjargal;
Row .3 from left to right: Dr. Artem Yermilov, Dr. German Kust.

ABOUT THE FIRST INTERNATIONAL WORKSHOP ON THE HUMAN DIMENSION OF CLIMATE AND ENVIRONMENTAL CHANGE

© 2005. E. Lioubimtseva

Geography and Planning Department, Grand Valley State University
1150 Au Sable Hall, 1 Campus Drike
Allendale, MI 49401, USA

There is a growing understanding among scientists, politicians and even general public in many parts of the world that local or regional environmental issues do have profound and irreversible implications at the global scale. We can very safely rephrase the popular slogan that we all learned in school: "think globally - act locally" into something we can much easier embrace: "think locally - act globally". We all have only one planet, we all depend on each other in this extremely interconnected world, and none of us can feel safe and happy while about every single place in this world is affected by human-induced environmental change.

The first international workshop on Human Dimensions of Climate and Environmental Change in Central Asia well exemplifies this growing understanding of strong relationships between global and local environmental issues and concerns. This conference was initiated by Grand Valley State University (USA) Geography and Planning Department in May 21-22, 2004 in Grand Rapids, Michigan, as a way to bring together scholars from all over the world to West Michigan to share research results, ongoing projects, and to chart a course for future collaboration to help resolve the environmental crisis in Central Asia.

Papers presented at the conference were diverse, reflecting the interdisciplinary nature of the conference and geographically the nationalities of the presenters represented a broad swath of Asia from Turkey to Mongolia and from Russia to Afghanistan. Researchers, professors and graduate students from Grand Valley State University (USA), Moscow State University (Russia), Caspian Institute of Biological Resources, Dagestan Scientific Centre of the Russian Academy of Sciences, Institute of Nuclear Physics of the National Nuclear Center (Kazakhstan), Central Asian Research Hydrometeorological Institute (Uzbekistan), Termez University (Uzbekistan), Samarkand University (Uzbekistan), Ben Gurion University (Israel), University of Nebraska (USA), Michigan State University (USA), University of Indiana (USA), Stuttgart University (Germany) were among the presenters. Keynote speakers were Dr. Philip Micklin, Professor Emeritus of Geography at Western Michigan University and internationally recognized specialist on Central Asian environments and Dr. German Kust, Vice-Director of the Soil Research Institute of the Russian Academy of Sciences and Moscow State University.

In the round-table discussions scientists from all over the world shared their findings, ideas, concerns and plans for future research in the Central Asia region. There was a general agreement among the participants that environmental situation in Central Asia requires attention of the global community and cannot be addressed solely at the local or regional scales.

We are very happy and honored that the selection of the best papers, presented at the first HDCECCA Conference is now published by Arid Ecosystems - an interdisciplinary international peer-reviewed journal with a great record of scholarly publication on arid environments of the World.

I would like to express my sincere gratitude to all people without whose help we would never be able to organize the first HDCECCA conference and publish this special issue: Kin Ma, Roy Cole, Wendy Wenner, Priscilla Kimboko, Erika King, Gayle Davis, Valery Neronov, Michael Glantz, Zalibek Zalibekov, Nina Novikova, Philip Micklin, German Kust, Rashid Kulmatov, Leon Palmer, Joe Kalee, Cindy Zehner, Artem Yermilov as well as many GVSU faculty, staff members and students who have worked with me on this project.

Elena Lioubimtseva, Chair of the HDCECCA Planning Committee.

========================= **ДОКЛАДЫ** ==================================

ВОДА И БУДУЩЕЕ БАССЕЙНА АРАЛЬСКОГО МОРЯ

© 2005 г. Ф. Миклин

Географический отдел, Западный Мичиганский университет
MI 49008 Каламазу, США

Чистая вода неотъемлемый элемент для выживания природы и общества. Она приобретает особое значение в аридных регионах земного шара. Одна из наиболее напряженных ситуаций в использовании этого ресурса сложилась в бассейне Аральского моря в Центральной Азии, где есть и хорошо увлажненные горы и обширные пустыни. Семь стран делят воды двух крупнейших рек: Амударьи и Сырдарьи, являющихся единственными источниками пресной воды. Из-за интенсивного развития орошения в пяти странах, которые в прошлом входили в состав СССР (Казахстан, Узбекистан, Киргизстан, Таджикистан и Туркменистан), расходуется более 90% водных запасов, главным образом для выращивания хлопка и риса. Уменьшение речных потоков и высыхание Аральского моря, куда впадают эти реки, стало причиной ряда серьезных проблем для окружающей среды и людей, включая разрушение доходной отрасли – рыболовства. Пыльные бури, поднимающиеся со дна высохшего моря, негативно отражаются на прилегающую территорию, изменяя климат вокруг бывшего побережья, начиная от морского берега до континентальных массивов. Все это ведет к прогрессирующему опустыниванию и связанной с ним экосистемной деградации дельт обоих рек, в особенности Амударьи, и к ухудшению здоровья и благосостояния населения обитающего в так называемой «зоне бедствия».

Пять государств бассейна Аральского моря, вышедших из Советского Союза, прилагают огромные усилия для решения вопросов в управлении ресурсами пресной воды. Эти страны создали межгосударственные организации для решения этой задачи через региональное сотрудничество, совместные научные исследования и финансирование.

Международное сообщество в сотрудничестве с региональными организациями оказывают существенную финансовую помощь, усиливая техническую оснащенность. Самыми важными и срочными задачами на сегодняшний день являются:

1) Проведение переговоров и подписание взаимно-приемлемых соглашений (включая Афганистан) о разделе потока Амударьи и Сырдарьи. Это является неотъемлемой существенной и устойчивой частью программы восстановления региона.
2) Применение технических, институционных и доступных экономических средств для улучшения орошаемого земледелия и сохранения воды.
3) Меры направленные для сохранения существующей части Аральского моря и дельтовых экосистем, что позволит облегчить положение населения в «зоне экологического бедствия». Успешное выполнение этих задач – главное условие в решении проблем окружающей среды, роста экономического и социального благосостояния, включая политическую стабильность в регионе.

WATER AND THE FUTURE OF THE ARAL SEA BASIN

© 2005. Philip Micklin

Dept. of Geography Western Michigan University
MI 49008, Kalamazoo, USA

Introduction

Water is biologically and physically essential to all life on earth (Micklin, 1996). Without an abundant supply in the liquid and gaseous state, plants, animals, and soils would neither have originated nor evolved to the complexity we find today. Although human physiological requirements are only a few liters of drinking water per capita, modern nations use prodigious quantities of this ubiquitous but precious substance. Fortunately, fresh water is a renewable resource, but in parts of the Globe, particularly the arid regions, anthropogenic actions have pushed usage to or beyond sustainable limits. Furthermore, competition among and within nations for fresh water, already a widespread problem by the end of the 20th Century, promises to become even more pervasive and acute in the new Millennium (Gleick, 2000).

Rivers, and groundwater, are the two major fresh water resources. Use of water from large rivers is particularly contentious because they not only pass through multiple regions within one country, but also frequently are shared between two, or among several, countries. According to the Transboundary Fresh Water Disputes Database project at Oregon State University, there are around 261 international rivers covering nearly half of the globe (www.transboundarywater.orst.edu). Five or more countries share 13 of these basins and 9 or more countries 4 (Fredericks, 1996). Competition for control and use of the flow of international rivers can lead to serious conflict among nations. Indeed, the fear of "water wars" has been postulated, by some, as one of the most serious threats of the 21st century (Wolf, 1998). However, shared rivers, if managed in a mutually agreed upon manner that is perceived as reasonably equitable by all riparians, can also be forces for cooperation among nations.

The purpose here is to examine the key problems of water resources' management in the Aral Sea Basin of Central Asia. Water is critical in this largely arid zone as irrigated agriculture remains the dominant economic pursuit. However, this activity has strained the basin's key fresh water resources, the Amu Dar'ya and Syr rivers, to the breaking point. Exacerbating matters is the sharing of these watercourses by multiple countries, which has lead to sharp differences among the riparians as to what constitutes an equitable water use allocation system. Excessive Irrigation has also resulted in the desiccation of the Aral Sea, accompanied by a plethora of negative human and ecological consequences.

The Aral Sea basin and its Water Resources

The Aral Sea Basin lies in the heart of Central Asia (Fig. 1). It covers a vast area, estimated at near 1.8 million km^2.(Tsentr, 1991, p. 4). The watershed includes territory of seven states: Uzbekistan, Turkmenistan, Kazakhstan, Afghanistan, Tajikistan, Kyrgyzstan and Iran. Lands that now constitute five of the seven basin states (Uzbekistan, Kazakhstan, Tajikistan, Turkmenistan, and Kyrgyzstan) were part of the Russian Empire and its successor, the Soviet Union, from the late 19th century until the collapse of the USSR in 1991. Eighty three percent of the basin was situated in the Soviet Union and over 90% of river flow came from its territory. Afghanistan and Iran control the residual portion of the watershed. A reasonable estimate of the basin population in 2004 is 53 million.

Fig. 1. The Aral Sea Basin of Central Asia

The central government of the Soviet Union made all critical water management decisions for the portion of the Aral Sea Basin it controlled until the USSR collapsed in 1991. The Ministry of Reclamation and Water Management (Minvodkhoz) in Moscow settled disputes among the republics over allocation and sharing of water from the international rivers. (Kilinskiy and Sheynin, 1986). The Soviet Union paid little heed to Afghan and Iranian water management views or interests. After the shattering of the USSR in 1991, the situation changed dramatically. The Aral Sea Basin and its water resources no longer were controlled by one super power. Suddenly, seven, states, five of which were new, shared the management responsibilities.

Geography and demography, however, condition some states to have much more interest in water management issues within the basin than others. All of Tajikistan and its population lie within the watershed, as do 99% of the territory and people of Uzbekistan. The basin accounts for close to 80% of Turkmenistan where nearly all its people live. Over 70% of Kyrgyzstan is in the basin and more than half its people reside here. Hence, these states have the paramount stake in basin-wide water management issues. Kazakhstan has 13% of its territory and 15% of its population in the watershed whereas Afghanistan has 40% of its area in the basin with 33% of its population there. They also have a significant interest in how basin water resources are handled. Iranian concerns with water issues are minimal as only 2% of its territory, located in the extreme northeast of the country, is in the basin and a minute portion of the national population (probably less than 1%) lives here.

The Amu Dar'ya and Syr Dar'ya

The Amu Dar'ya [1] is the premier river of the Aral Sea Basin. It flows nearly 2400 km from the glaciers and snowfields of the Pamir Mountains of Tajikistan, Kyrgyzstan and Afghanistan across the Kara-Kum desert into the Aral Sea. The river, or its major tributaries, course along the borders and across four states: Tajikistan, Afghanistan, Turkmenistan, and Uzbekistan (Fig. 1). Average annual flow from the drainage basin is around 79 km^3, including 62 km^3 from the Amu Dar'ya and 17 km^3 from several other rivers that terminate in the desert before reaching the main stem of the Amu. The Amu Dar'ya is "exotic", i.e., essentially all its water originates in the Pamir Mountains, but is substantially diminished crossing the Kara–Kum desert to the Aral. Tajikistan contributes 80% of flow generated in the Amu Dar'ya basin, followed by Afghanistan (8%), Uzbekistan (6%), Kyrgyzstan (3%) and Turkmenistan and Iran together around 3% (most of which is formed in Iran) (McKinney and Akmansoy, 1998; ICAS, 1996, chapter 6)

The Syr Dar'ya with a length of 2,500 km originates in the Tyan' Shan Mountains, to the north of the Pamirs. Glaciers and snowmelt are its chief sources of water. The river flows from Kyrgyzstan into Uzbekistan, then across a narrow strip of Tajikistan into Uzbekistan, and finally across Kazakhstan and into the Aral Sea. Average annual discharge of the Syr Dar'ya, is 37 km^3. Kyrgyzstan contributes 74% of river flow, Uzbekistan 11%, Kazakhstan 12%, and Tajikistan 3%. This river also has an "exotic" character.

The rivers of the Aral Sea Basin provide on an annual average basis around 116 km^3. Estimates of usable groundwater range from 13 to 17 km^3/yr (Micklin, 1991, p. 99; Dukhovnyy and Sokolov, no date, p. 3). Thus, potentially usable water resources may be as much as 133 km^3. On a per capita basis (assuming a 2004 basin population of around 53 million), they equal 2,509 cubic meters/person, which is substantial. However, the per capita figure hides the sharp spatial discontinuities of the region in terms of where flow is generated and where people live and use water most heavily. In hydrologic/geographic terms the region may be divided into two zones. First is the flow-generating, sparsely inhabited, upstream mountains, where water use is low. Occupying only 20% of the basin, it generates 90% of the flow for the Amu Dar'ya and Syr Dar'ya (Matmakanov, 1996, pp. 5-7). Second are the downstream arid plains (covering 80% of the basin), where most of the populace resides along and near the rivers and major canals. It is here that most of the water is withdrawn, and whose indigenous water resources are far less than use. The deficit in the plains is, of course, covered by outflows from the well-watered mountains.

[1] Dar'ya in the Turkic languages of Central Asia means river.

Tajikistan and Kyrgyzstan, occupying the core of the Aral Sea Basin mountain zone are “water rich”. The former supplies 55% of average annual basin river flow and the latter 25%, for an aggregate contribution of 80%. Water withdrawals for the two countries together in 1995 were only 16% of the total. These states are large net donors to basin water supplies. Afghanistan is also a net donor as it provides about 5% of Aral Sea Basin river flow, but had withdrawals in 1995 that were likely not more than 1% of the total (World Bank, p. 16).

On the other hand, the downstream states of Uzbekistan, Kazakhstan, and Turkmenistan are “water poor” and large net consumers of basin water resources. Situated primarily on the arid plains of the Central Asian deserts, they contribute only 14% of Aral Sea Basin river flow. These nations accounted for 83% of estimated basin withdrawals of 111 km^3 in 1995. Uzbekistan contributes 8% of basin flow but its withdrawals in 1995 were 52% of the total. Turkmenistan contributes essentially no flow but is a major consumer accounting for 20% of withdrawals in 1995. Kazakhstan contributes 4% of aggregate basin flow, but 13% of the flow for the Syr Dar’ya while withdrawing 10% of basin totals in 1995. Iran contributes about 3% of basin flow and consumes, at most, 1%.

Sufficiency of Renewable Water Resources

As noted above, a reasonable estimate of average annual renewable water resources, both surface and ground, is 133 km^3. We can add to this an estimated 40 km^3 of flow that has been withdrawn but returned to river channels or dumped into closed depressions in the deserts to evaporate to give an upper limit of more than 170 km^3/yr. as the potentially usable water resources in the basin (ICAS, 1996, Chapter 6). .From 1990 to 1995, annual water withdrawals ranged from 111 km^3 to 126 km^3 (Dukhovnyy, 1993, p. 56; ICAS, 1996, Chapter 7, tables 7.1 and 7.2). Comparing withdrawals with potential supply suggests that there is plenty of water to go around for all basin countries and users, now and for the foreseeable future.

The situation, unfortunately, is more complex and less sanguine. First, we must subtract unavoidable flow losses such as filtration from riverbeds, evaporation from reservoirs, and evapo-transpiration from phreatophytes. These may run to 16 km^3 annually for the Amu Dar’ya and Syr Dar’ya (Micklin, 2000, p. 10). Second, river flow is uneven on an intra- and inter-annual basis. To harmonize water demand with river flow, large dams and reservoirs are built to store water during high flow periods (spring and early summer) and years for use during summer low flow periods of high demand and low flow years (Micklin, 1991, pp. 4-7). However, attempting to store all the seasonal surplus flow, and especially the surplus flow in high water years, for times when flow is low and demand is high lacks both economic and environmental justification (Collier *et al*, 1996; Micklin 1996).

Seasonal and multiyear storage dams and reservoirs have been built on both the Amu Dar’ya and Syr Dar’ya. This has increased the ensured yield of water, a measure of availability in a low flow year (which, statistically speaking, occurs on average once in ten years) to 79 km^3 for both river basins. The amount of water that is available in the low flow years is, in fact, most crucial for water resource management. It is more indicative of the state of water resources in arid regions such as the Aral Sea Basin than the average annual figure, which is over-weighted by the high flow years, much of whose flow neither can be stored nor used.

In light of the above (and realizing that low flow years usually occur in cycles in arid regions rather than being randomly distributed) the water supply vs. use situation for the Aral Sea Basin looks much less favorable. Taking the 79 km^3 figure for a low flow year and subtracting “unavoidable” losses of 16 km^3, leaves only 64 km^3 as the potentially usable resource. Adding return flows of 40 km^3 and groundwater additions of 17 km^3, to this gives a total available resource of 121 km^3. This figure falls within the range of withdrawals for the period 1990-95. Actually, during low flow periods, withdrawals from the Amu Dar’ya and Syr Dar’ya in the downstream net consuming countries of Uzbekistan, Kazakhstan, and Turkmenistan are, of necessity, substantially reduced. It is during these cycles (most recently 1999-2001) that tensions rise between the upstream and downstream states and among the downstream nations over the allocation to each of a reduced water supply.

The Aral Sea Problem

Further exacerbating the water situation in the Aral Sea Basin is the plight of the Aral Sea. Located amidst the great deserts of Central Asia (Fig. 1), this lake is fundamentally dependent on flow from the Amu Dar'ya and Syr Dar'ya to maintain its size and ecological integrity. Kazahstan and Uzbekistan are riparian on the Sea proper, with each possessing an approximately equal length of shoreline. The entire Aral coastline within Uzbekistan lies within that nation's Karakalpakstan Republic. A terminal lake, it has surface inflow but no surface outflow. Therefore, the balance between inflows from the two rivers and net evaporation (evaporation from its surface minus precipitation on it) fundamentally determine its level. Over the last 10,000-15,000 years, the sea's level has fluctuated as much as 40 meters (Micklin, 1991, p. 42-43; Kes' 1978).[2] For the initial period of instrumental observation (1911-1960), annual inflow and net evaporation averaging near 55 km^3 and level variations were less than one meter. (Bortnik and Chistyaevaya, 1990, p. 36; Micklin, 1994).

The Aral Sea, according to area, was the world's fourth largest inland water body in 1960 (Micklin, 1991, pp. 42-54). With salinity around 10 g/l it was inhabited by twenty indigenous fresh water species. The sea supported a major fishery and functioned as a key regional transportation route. The extensive deltas of the Syr Dar'ya and Amu Dar'ya sustained a diversity of flora and fauna. They also supported irrigated agriculture, animal husbandry, hunting and trapping, fishing, and harvesting of reeds, which served as fodder for livestock as well as building materials.

Over the past four decades, primarily as a result of growing irrigation, the sea has steadily shrunk and salinized (Figure 2, Table 1). The Aral separated into two water bodies in 1987 - a

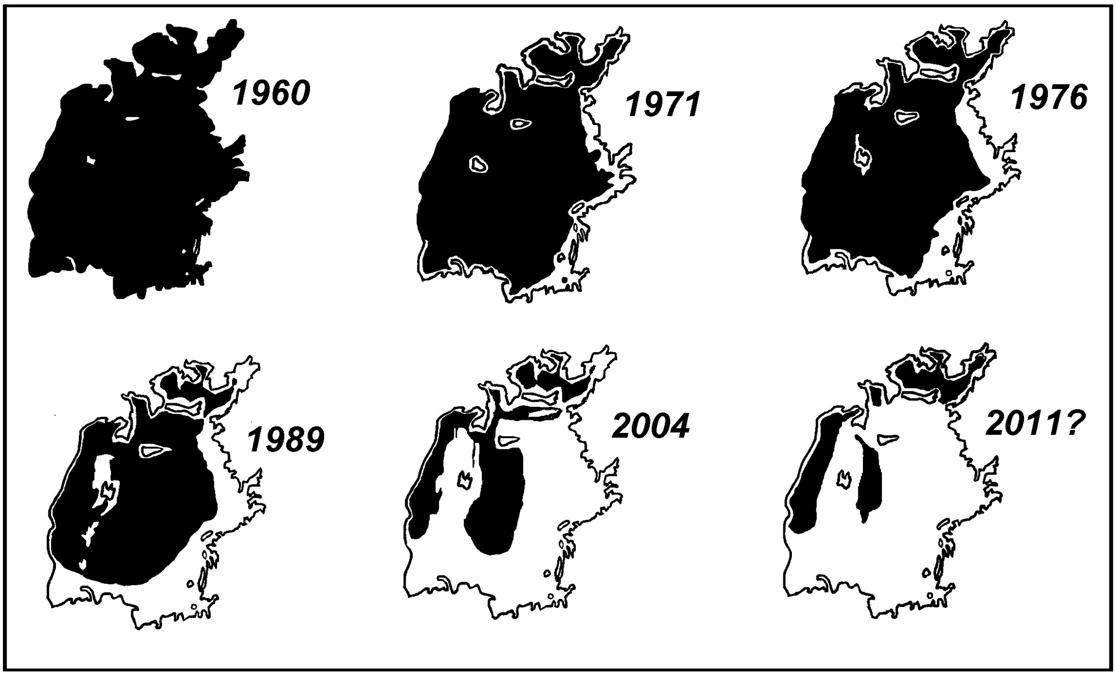

Fig. 2. The Changing Profile of the Aral Sea

small Aral Sea in the north and a large Aral Sea in the south. The Syr Dar'ya flows into the former, and the Amu Dar'ya into the latter. Between 1960 and January 2004, the level of the small Aral fell by 13 meters and the large Aral by 23 meters. The area of both seas taken together diminished by 75 % and the volume by 90%. Salinity in the small sea is estimated to have doubled whereas in the large sea it has

[2] The major level changes prior to 1960 resulted from diversion of the Amu Dar'ya westward so that it flowed into the Sarykamysh hollow (and sometimes farther through the Uzboy channel to the Caspian Sea after it overtopped Sarykamysh) rather than the Aral Sea. These diversions resulted from natural events (sedimentation of the bed and subsequent breaching of the rivers left bank during spring floods) and from advertant human actions (destruction of dikes and levees, built to keep the river flowing to the Aral, during times of conflict).

increased by seven to over 10 fold. Within a few years the large Aral is will ivide into three parts - a “deep” western lake,” shallow” eastern lake, and small northern lake.

The desiccation of the Aral Sea and associated degradation its two influent rivers has had severe negative impacts (Micklin, 2000, pp. 13-23). Besides the consequences for the sea proper, a zone around the waterbody of several hundred thousand square kilometers with a population of several million has also been damaged. (Khvorog, 1992). The Republic of Karakalpakstan in Uzbekistan and portions of Kzyl-Orda Oblast in Kazakhstan, have suffered the most harm. Dashauz Oblast in Turkmenistan has been substantially impacted. The territory suffering significant impacts, however, is a small part of each country’s area and contains a minor portion of its population. The other states of the Aral Sea Basin are distant from the zone of intense effects; they have suffered no demonstrable harm from the drying of the sea.

The substantial Aral fishing industry in Kazakhstan and Uzbekistan collapsed by 1983 as the commercially important indigenous species disappeared from the sea owing to rising salinity and loss of shallow spawning and feeding areas (Micklin, 2000, p. 16; Micklin, 1991, pp. 49-50; Williams and Aladin, 1991; Zholdasova et. al., 1998; Ptichnikov, 2002). However, all of these still survive in the deltaic lakes and Amu Dar’ya and Syr Dar’ya rivers. A few of the introduced salt-tolerant fishes remain, mainly in the much less saline small Aral, but these will soon vanish from the large Aral Sea as salinity continues rising. The loss of the fishery through tens-of-thousands out of work.

The rich and diverse ecosystems of the Amu Dar’ya delta have suffered particular harm (Micklin, 1991, pp. 50-52). Greatly reduced river flows through the delta, the elimination of spring floods, and declining ground water levels have resulted in spreading desertification . Halophytes and xerophytes are rapidly replacing endemic vegetation communities (Novikova, 1996). Expanses of unique tugay forest that formerly stretched along all the main rivers and distributary channels have been devastated[3]. These zones are habitat for a diversity of animals, including 60 species of mammals, more than 300 types of birds and 20 varieties of amphibians.

Desiccation of the delta has significantly diminished the area of lakes, wetlands, and their associated reed communities. Between 1960s and 1980s, the area of lakes in the Amu Dar’ya delta is estimated to have decreased from 49,000 to 8,000 km^2 and the area of reeds from 500,000 ha to as little as 1,000 ha (Chub, 2000, Fig. 3.3, p. 125; Palvaniyazov, 1989) [4]. These zones provide prime habitat for a variety of permanent and migratory waterfowl. A recent report notes that of 282 bird species formerly observed in the Amu Dar’ya wetlands, around 30 have disappeared and some 88 are listed as rare (UNESCO, 2000, pp. 44-46).

Irrigated agriculture in the delta of the Amu Dar’ya has also suffered from reduced river flow of elevated salinity, caused by return flows from upstream irrigation (World Bank, 1998, pp. 3-5). Application of such water to crops lowers yields and contributes to rising ground water levels and secondary soil salinization (Bucknall *et al*, 2003, pp. 8-12). Livestock raising in the delta and desert regions adjacent to the Aral Sea has suffered from degradation of pastures and replacement of natural vegetation suitable for grazing by inedible species.

Strong winds blow sand, salt and dust from the dried bottom of the Aral Sea, now largely a barren, salt covered desert with an area near 50,000 km^2, onto adjacent lands. Satellite images reveal major salt/dust plumes extending 200 to more than 500 km, allowing dust and salt to settle over a considerable area adjacent to the sea in Uzbekistan, Kazakhstan, and to a lesser degree, in Turkmenistan (Micklin, 1991, pp. 48-49; Glazovskiy, 1990, pp. 20-23; Ptichnikov, 2002). The most seriously affected areas are the Ust-Urt Plateau to the sea’s west and the Amu Dar’ya delta at the south end of the water body (Bortnik and Chistyaevaya, 1990, p. 27, Fig. 2.7). Salt and dust settle on natural vegetation and crops in the Amu Dar’ya delta, killing them or retarding their growth. These materials also contribute to respiratory illnesses, eye problems, and possibly esophageal cancer (Abdirov et. al, 1993; Tursunov,

[3] According to Novikova (1996), a Russian expert, whereas Tugay covered 100,000 ha in the Amu Dar’ya delta in 1950, it shrank to 52,000 ha by the 1970s and to only 15-20,000 ha by the mid-1990s.

[4] However, in the late 1980s and in the 1990s, significant efforts were made to restore wetlands and their reed communities and to improve habitat conditions (Chub, 2000, p. 125).

1989). More recent field work reveals salt and dust from the dried bottom (and from irrigated farmland in regions adjacent to the Aral Sea) is laced with pesticides and heavy metals (O'Hara et. al., 2000).

Owing to the sea's shrinkage, climate has changed in a band up to 100 km wide along the former shoreline in Kazakhstan and Uzbekistan (Micklin, 1991, pp. 52-53; Glazovskiy, 1990, pp. 19-21). Maritime conditions have been replaced by more continental and deseritic regimes. Summers have warmed and winters cooled, spring frosts are later and fall frosts earlier, humidity is lower, and the growing season shorter. Uzbekistani climate experts believe that the increase in the levels of salt and dust in the atmosphere are reducing solar radiation reaching the surface and, thereby, photosynthetic activity as will as increasing the acidity of precipitation (Chub, 1998).

The population living in the "ecological disaster zone", particulary in Karakalpkstan, suffers acute health problems (Micklin, 1992; Medicins sans Frontieres, 2000; UNESCO, 2003, pp. 36-43). Some of these are direct consequences of the sea's recession or environmental pollution as mentioned above. However, the most serious health issues are directly related to 'Third World' medical, health, nutrition and hygienic conditions and practices. Bacterial contamination of drinking water is pervasive and has led to very high rates of typhoid, paratyphoid, viral hepatitis, and dysentery. Tuberculosis is prevalent as is anemia, particularly in pregnant woman. Liver and kidney ailments are widespread; the latter is probably closely related to the excessively high salt content of much of the drinking water. Medical care is very poor, diets lack variety, and adequate sewage systems are rare.

The most ironic and dark consequence of the Aral's shrinkage is the story of Vozrozhdeniya (Resurrection) Island. The Soviet military in the early 1950s selected this, at the time tiny, isolated island in the middle of the Aral Sea, as the primary testing ground for its super-secret biological weapons program (Bozheva et. al., 1999; Wijinsema, 2000;). From then until 1990, they tested various genetically modified and "weaponized" pathogens there. These programs stopped with the collapse of the USSR in 1991, but, allegedly, decontamination measures were incomplete. By 2001, the formerly small island grew into a huge peninsula and united with the mainland. If, as believed, weaponized organisms survived, they could escape to the mainland via infected rodents or terrorists might gain access to them. The U.S. has committed $6,000,000 to help the Government of Uzbekistan kill any surviving organisms (Science Scope, 2002).

If from 1911-1960, discharge to the sea from the Amu Dar'ya and Syr Dar'ya averaged 55 km^3/yr., for the 1980s, it had fallen to 6 km^3 (Hydrologic data, 1984-2003). The period 1990-98 was characterized by a cycle of above average flow years with estimated inflow to the sea for this period averaging 14-15 km^3. Severe drought affected the flow generating mountains of the Aral Sea basin from 1999 through 2001 (Agrawala *et al*, 2001). Average annual inflow to the Aral Sea for this period was probably no more than 2 km^3. Assuming continuation of the pattern of recent basin withdrawals, it is likely that average annual inflow to the sea in the near-term future will not be more than 10 km^3.

Thus, to restore the Aral to its size during the first six decades of the 20th century would require raising average annual discharge to the sea by approximately 45 km^3, or 450 percent, bringing total inflow to 55 km^3. This would necessitate a larger decrease in upstream withdrawals to compensate for natural losses of the net additions to flow before they reached the sea. Assuming these at 14%, an additional 7 km3 reduction would be required for a total of 52 km^3. That such a lowering of upstream use (47% of 1995 withdrawals) could be attained in the foreseeable future without causing economic and social havoc for the main irrigating countries of the basin seems remote. Even to stabilize the sea at its January 2004 size of 17,158 km^2 would require an inflow increase to around 14 km^3, 40% above the 10 km^3 future average annual figure cited above. Upstream withdrawals would need to be reduced an additional 0.6 km^3, for a total of approximately 14.5 km^3. During the higher flow period of 1990-1998 there was insufficient discharge to stop the sea's recession. In dry cycles (e.g., the 1980s and 1999 through 2001), practically no water reached the sea and desiccation proceeded alarmingly rapidly.

In light of the above discussions, it is manifestly clear that exploitation of water resources in the Aral Sea Basin has been pushed far beyond the level of sustainability. This begs several interrelated questions. (1) What could be done to increase water availability in the Aral Sea Basin and what are the main impediments to this? (2) What is the status of interstate management of the key shared water resources, the Amu Dar'ya, Syr Dar'ya, and Aral Sea? (3) What has been the role of foreign aid donors in improving the water management situation in the Aral Sea Basin? (4) What does the future of hold for water management in this region?

Enhancing Water Availability

From the early 1970s to mid-1980s, the Soviet government proposed diversion of massive flow from Siberian rivers into the Aral Sea Basin as the panacea for solving water shortage problems (see Micklin, 1991, pp. 66-68 and Timashev, 2003 for discussion of this proposal). The project was on the brink of implementation when stopped by the Gorbachev regime. Although this grandiose scheme continues to be discussed and promoted by high governmental officials in Central Asia and some water management specialists and scientists in Russia and Central Asia, implementation in the foreseeable future, if ever, for a variety of reasons, including costs, environmental consequences, and political realities are slight ("Considering the revival…" 2003). Other measures could be implemented such as more use of groundwater, local rainwater harvesting and storage that could add somewhat to water availability.

However, substantial water savings are only obtainable from irrigated agriculture, which encompasses around 7.9 million ha in the Aral Sea Basin. Irrigation accounts for 92% of withdrawals and an even larger share of consumptive use (Ruziev and Prikhod'ko, 2002;).[5] . It is irrigation that has depleted the flow of the Amu Dar'ya and Syr Dar'ya and led to the great reduction in discharge of these rivers to the Aral.

A substantial reduction in the area irrigated could save much water, but is highly unlikely. All the basin states except Kazakhstan plan to continue expanding irrigation; mainly to meet the food needs of a growing population (ICAS, 1996, Chapter 6; Antonov, 1996). Major savings, therefore, depend on improvements in use efficiency and replacement of highly water consumptive crops with lower-use varieties. Net water savings from substantial technical improvements in irrigation could range from 12 to 27 km^3 annually. But, such a program would take decades to implement and to reach even the lower figure would cost in the neighborhood of 16 billion in U.S. dollars. This is far beyond the willingness and ability of the basin states, in combination with international donors, to pay. Exacerbating matters is the worsening technical condition of irrigation systems in the basin. (See Micklin, 2002 and Bucknall, 2003 for a more detailed discussion of these issues).

Switching from high water use crops (rice and cotton) toward lower (grains, vegetables, melons, fruits, and soy beans) would be a relatively low cost means of reducing water use. In fact, the reason irrigation water withdrawals in the basin reportedly declined from 109 to 92 km^3 between 1990 and 1997, while the irrigated hectarage grew nearly 10%, can be largely attributed to the conversion of some cotton growing fields to grains (mostly winter wheat) (Dukhovnyy and Sokolov, no date, pp. 7-11). However, there are limits to such a program as the two primary irrigating nations (Uzbekistan and Turkmenistan) are intent on keeping cotton as a major crop since it plays a key role in earning foreign currency.

Economic reform, land reform and institutional change in irrigated agriculture could also improve matters. Of primary importance would be irrigation water pricing, privatization of land, and giving rights of self-governance and responsibility for management of on-farm and inter-farm irrigation systems to farmer-irrigators by establishing water user associations (WUAs) (Information 1996-97). Kazakhstan and particularly Kyrgyzstan, have taken some serious steps in these directions. Tajikistan is beginning efforts whereas in Uzbekistan there is talk but not much meaningful action to implement such policies. Turkmenistan has done practically nothing. Among the key obstacles are governmental resistance, opposition from the former collective (now cooperative) farms and local officials, fear of land speculation and exacerbating rural underemployment and unemployment, an inappropriate structure of water management and distribution agencies, lack of means to measure water deliveries to

[5] Withdrawals are a measure of the total water taken from sources (rivers and groundwater) for irrigation. Consumptive use is a measure of the water that is withdrawn that is lost to evaporation (from conveyance canals and fields) and transpired from or incorporated into crops. The difference between the two is termed return flow. Return flow includes filtration from canals, filtration from fields, and surface runoff from fields. Part of return flow ultimately reaches the river from which taken or adds to groundwater while another portion runs off into desert hollows to form lakes (the water from these is lost to evaporation

farmers, and the impoverished state of the farming economy. (see Micklin, 2000, pp. 54-67, Butterfield, 2002, Bucknall, 2003, and Wegerich, 2004 for a detailed discussion of these issues).

The major burden in reducing irrigation water usage must rest on Uzbekistan as it has the largest irrigated area and accounts for the majority (54%) of irrigation withdrawals in the Aral Sea Basin. Turkmenistan, second in irrigated area and water withdrawals (22%), could also make substantial contributions to water savings. The remaining states that were part of the USSR (Tajikistan, Kazakhstan and Kyrgyzstan) could make significant, but much smaller contributions. Afghanistan and Iran withdraw very little water from the basin.

Interstate Management of the Amu Dar'ya, Syr Dar'ya and Aral Sea

Realizing they needed institutional mechanisms for the management of interstate water resources in the post-Soviet era, the Aral Sea Basin republics of the former Soviet Union signed an agreement in February 1992 on the joint management and protection of interstate water resources (ICWC,1997, pp. 4-8; Dukhovnyy and Sokolov, no date, pp. 12-15; UNESCO 2000, pp. 51-55). The agreement created an Interstate Commission on Water Coordination (ICWC).

The Commission meets several times each year to decide interstate water management policy issues, to set the allocation of water for the up coming hydrologic year (October through September) among the republics and to the Aral Sea and its deltas based on forecasts of water availability. The allocation scheme essentially continues the distribution formula in place during the last years of the USSR. Determination of operating regimes for the reservoirs along the interstate rivers was also placed on the ICWC. Inter-republic water management disputes are to be decided by the Commission. The ICWC consists of a Secretariat, Scientific Information Center, and the basin management authorities or BVOs.[6] for the Syr Dar'ya (in Tashkent, Uzbekistan) and Amu Dar'ya (in Urgench, Uzbekistan). The BVOs are the bodies charged with managing and monitoring the allocations made by the ICWC to member states.

The water-sharing scheme is heavily tilted toward irrigation and the interests of the downstream riparian states. Uzbekistan and Turkmenistan receive the largest shares from the Amu Dar'ya whereas Uzbekistan and Kazahstan are allocated the lions share of the withdrawals from the Syr Dar'ya (Micklin, 2000, Table 6). The upstream flow generating states are given the residual. The ICWC allots the residual flow of the Amu Dar'ya and Syr Dar'ya to the Aral Sea region. Earlier, the Aral Sea region did not have a specific allocation. During very dry periods, such (e.g., 1999-2001), the ICWC makes across the board (percentage) reductions in allocations (MKVK, 2002a, 2002b).

Tajikistan and particularly Kyrgyzstan, have complained about the allocation scheme. Their mountain territories generate 80% of the flow in the basin of the Aral Sea, yet their allowed withdrawals are miniscule compared with the share assigned to Uzbekistan, Kazakhstan, and Turkmenistan. Furthermore, to serve irrigation, most of the flow must be accumulated in reservoirs on their territories and released during the growing season, restricting the ability of these countries to generate winter hydroelectricity. This is a particularly serious problem for Kyrgystan since it has faced chronic winter energy shortages after independence, as deliveries of coal (from Kazakhstan) and gas (from Uzbekistan) have been frequently interrupted. In Soviet times these deliveries were guaranteed by the central government.

Turkmenistan, Kazakhstan, and especially Uzbekistan want to see the existing allocation schemes and operational regimes continued (Micklin, 2002, Pannier, 2000, Krutov and Lennaerts, 2000; Gleason, 2001; "Considering the revival…" 2003). On the other hand, Kyrgyzstan and Tajikistan want considerably more of the flow allocated to them (so they can expand irrigation) and more freedom to generate winter hydropower. Kyrgyzstan has repeatedly violated winter release limits at the huge Toktogul reservoir on the Naryn, the chief tributary of the Syr Dar'ya, reducing water available during the following summer season for downstream irrigation. It also has caused winter flooding in

[6] This acronym is from the Russian title of these organizations, *Basseynovoye vodokhozyaystvennoye ob"yedinennoye,* which means Basin water management association

Uzbekistan and Kazakhstan, forcing emergency diversion of flow, which should go the Aral Sea, to the huge, artificial Lake Arnasay in the desert.

There are also allocation conflicts among the downstream states. The most serious is the disagreement between Uzbekistan and Turkmenistan over the Kara-Kum Canal. Under construction since the mid-1950s, the almost 1400 km long canal is allocated 13 km^3 annually from the Amu Dar'ya (Hannan and O'Hara, 1998). This facility irrigates almost one million ha in Turkmenistan and is the source of municipal water supply for the capital of Ashgabat. The Turkmen government considers the canal fundamental to national survival and is intent on lengthening it and irrigating even larger areas. On the other hand, the Uzbek government views the unlined Kara-Kum as a manmade river flowing through the desert that loses huge amounts of water to filtration. Owing to lack of maintenance, the canal is rapidly deteriorating, which further increases water losses from it.

In March 1993, the presidents of the five republics established the Interstate Council on the Problems of the Aral Sea Basin (ICAS) and an International Fund for the Aral Sea (IFAS) (Agreement, 1993; UNESCO, 2000, pp. 51-52). The major responsibility of ICAS was to facilitate assistance from the World Bank and other international donors (Micklin, 1998, pp. 406-409) whereas IFAS was charged with collecting revenue from each basin state for financing of rehabilitation efforts. ICAS was abolished in 1997 and its functions assumed by a restructured IFAS.

International Donor Efforts

Since the breakup of the USSR, international aid donors have played a major role in promoting cooperation in the management of the international water resources of the Aral Sea Basin (Micklin, 1998). In the early 1990s, The World Bank formulated an Aral Sea Basin Assistance Program (ASBP) to be carried out over 15 to 20 years with a cost that could run to nearly $500 million.. The Bank encouraged the basin states to create ICAS and IFAS and has worked with and through these organizations to realize the ASBP. Afghanistan was invited to join the ASBP but did not respond to the overture (World Bank, 1998, p. 9).

The latest aspect of the Bank funded effort, supported through the Global Environmental Facility (GEF), is the Water and Environmental Management Project (World Bank, 1998, pp. 19-34). At a cost of $21.5 million , the project started in 1998 and finished in 2003. In line with a new emphasis on regional responsibility for the ASBP, the Executive Committee of IFAS managed the program, with the Bank playing a cooperative/advisory role.

The United States Agency for International Development (USAID) funded the Environmental Policy and Technology (EPT) project, running from 1993 to 1998, which financed measures to improve drinking water supplies in the Amu Dar'ya delta, aided in the formulation and implementation of regional water management policies and agreements, and provided advice on water management issues to specific governments (Micklin 1998). Perhaps its most important accomplishment was helping the states riparian on the Syr Dar'ya reduce tensions over the proper operation of the Toktogul dam and reservoir on that river (Micklin, 1998). USAID initiated a new effort in 2001 known as the Natural Resource Management Project (NRMP) (for information, see the project website at www.nrmp.uz). This is a 5-year effort focusing on providing assistance to Kazakhstan, Kyrgyzstan, Turkmenistan, Uzbekistan and, to a lesser extent Tajikstan, to improve management of water, energy, and land. As part of the water component, the NRMP is continuing the earlier work to enhance interstate cooperation and sharing of the Syr Dar'ya' flow.

The European Union (EU) began major aid programs for the Aral Sea Basin states in 1995 (Micklin, 1998). Key objectives have been to assist the five former Soviet republics to develop policies, strategies and development programs for utilization, allocation and management of the water resources of the basin; and to assist at the regional level with the establishment of the institutional structure for allocation and management of interstate waters.

The United Nations has been providing assistance on the Aral Sea Crisis since 1990 when it formed a joint UNEP (United Nations Environment Program)/Soviet working group on the Aral (Micklin, 1998). UNESCO (United Nations Educational, Scientific and Cultural Organization) funded a research and monitoring program for the near Aral region from 1992-1996 focusing on the Syr Dar'ya and Amu

Dar'ya deltas (UNESCO, 1998). UNICEF (United Nations Childrens' Fund) launched the Aral Sea Project for Environmental and Regional Assistance (ASPERA) in 1995. UNDP (United Nations Development Program) has worked to strengthen regional organizations (ICAS and IFAS) and promoted sustainable development to improve conditions for the several million people in the disaster zone closest to the Aral Sea. UNDP also convened the International Conference on the Sustainable Development of the Aral Sea Basin in September 1995, which led to the signing by the five Central Asian presidents of a declaration on the sustainable development of the Aral Sea Basin. The five Presidents reaffirmed the sustainable development goals in the 1999 Ashgabat Declaration (UNESCO, 2000, p. 53).

The North Atlantic Treaty Organization (NATO) has been active in Aral Sea region activities through its Scientific and Environmental Affairs Division. It has sponsored several workshops with Aral Sea themes as well as long-term aid projects aimed at improving indigenous scientific research and environmental monitoring capabilities in the Aral Sea region (Micklin and Williams 1996). (For more information on NATO funded efforts see NATO/OTAN, 2003, pp. 153-154 and 189-190, SfP 974101 website at http://sfpp.nm.ru and SfP 974357 website at http://www.icwc-aral.uz).

The Future

What does the future hold in terms of water resource management for the Aral Sea Basin and what may be some key ramifications of the manner in which this resource is handled? The Aral Sea Basin has considerable freshwater resources. However, taking into account natural variability of these rivers' discharge and the associated problem of storing surplus flow and the situation of the Aral Sea, there is no doubt basin water supplies are substantially overexploited, particularly during cycles of low-water years.

The key problem is irrigated agriculture. Substantial water savings must come from improvements in this sector. Without these, growth of irrigation and other water uses not only will be difficult, but also contribute to conflict as the basin states compete to maximize their share of the resource. Implementation of water-saving improvements in irrigation are key not only to economic and social improvement but would be a fundamental means of promoting cooperation in water management among the basin states and avoiding conflict. Large-scale technical rehabilitation and modernization of irrigation systems is of fundamental importance, but would be exceptionally costly. Implementation of such efforts in the near term seems remote. Crop substitution is a much cheaper route to significant water savings. Yet, if done on a scale large enough to have a significant effect on water use, would force a sizable reduction in cotton production, the chief export crop for Uzbekistan and Turkmenistan.

Adoption of fundamental economic and institutional reforms within irrigated agriculture has great promise to improve this sector and save water. Meaningful irrigation water pricing, privatization of land on the Western model, and granting rights of self-governance and responsibility for management of irrigation systems to farmer-irrigators are the most needed steps (Micklin, 2000, pp.54-67; Bucknall 2003; Horinkova and Abdullayev, 2003). Melding traditional methods of small-scale irrigation with modern irrigation technology could be part of this program.

Progress has been made in the reform effort. Kazakhstan and Kyrgyzstan have abolished State and Collective farms, are implementing true privatization of land and the placing of agricultural decision-making in the hands of farmers and have introduced irrigation water pricing. Uzbekistan has ended the State Farm system, given more freedom to the Cooperatives, allowed forms of quasi-private farming and abolished state orders for all crops. Tajikistan has stated an intention to convert State and Collective farms to Cooperatives and to encourage private sector agriculture. Except for Turkmenistan, the former Soviet republics are pursuing creation of agricultural water user associations (WUAs) (Baxter, 2002).

Nevertheless, huge obstacles remain. Farmers are impoverished and cannot pay more than a token charge for water. Kazakhstan and Kyrgyzstan are facing significant opposition from rural constituencies to agricultural reform. Land in Uzbekistan and Turkmenistan remains state property (Butterfield, 2002). Both governments still exert strong control of agriculture and water management, reminiscent of the former Soviet system. In fairness, The Uzbekistani leadership has articulated some legitimate reasons and concerns for going slow on reform related to protecting the interests and welfare of the rural population in densely settled regions, avoiding excessive land speculation and 'land grabs' by the rich, trying to avoid ethnically-based conflicts over land and water as have occurred in the Fergana Valley, preserving prime agricultural land from conversion to non-agricultural uses, and protecting the state monopsony (one buyer) on cotton - that government's main source of foreign exchange.

Corruption and patronage remain endemic, society-wide problems. These hinder reform efforts in the agriculture and water management sectors as they divert funds from their most productive uses, discourage reform efforts at the local level, hinder competent, but not politically connected, people from advancing in the agriculture and water management institutional structure, and make access to land and water more dependent on bribes, connections, and cronyism than ability to use these resources most productively (Bucknall, 2003). Prospects for mitigating the situation in the near term appear rather dim.

Population growth and anthropogenically induced climate change are likely to worsen an already difficult water resource situation. Basin population could easily grow to 60 million by 2020, a 13% increase over today. The need to provide employment and food for a significantly larger population is a rationale for a substantial increase in irrigation that could use up water saved from implementation of improvement measures. Global climate warming, according to most experts, is likely already underway and will increase in magnitude with time. The prevailing wisdom of local experts is that a general warming of 0.5 to 3.5 centigrade degrees is possible in different regions of the Aral Sea Basin by 2030 compared to the base period of 1961-1990 (Chub, 2000, pp. 62-106). This would lead to longer, hotter summers with increased crop water needs and heightened irrigation requirements. The flow of the Amu Dar'ya and Syr Dar'ya could be somewhat increased by enhanced precipitation and melting of glaciers, but is unsustainable as the rate of melt of the glaciers would exceed their replenishment (Chub, 2000, pp. 106-115).

How the basin states approach sharing the Amu Dar'ya and Syr Dar'ya is crucial to whether conflict or cooperation will be the dominant theme in future management of these international rivers. Inherent water management conflicts exist between the upstream and downstream states as the former are net providers of water and the latter are net users. Furthermore, the upstream states benefit from operating the large hydroelectric stations on their territory to maximize winter hydropower production, which is counter to the interests of downstream irrigating states that need maximum releases during the summer. Serious differences also have developed between downstream Uzbekistan and Turkmenistan over the Kara-Kum Canal.

Two other factors make matters worse. The period from independence in 1991 through 1998 was one of higher than average river flow (Micklin, 2000, p. 21). This instilled in the basin states a false sense of water availability and security. The subsequent inevitable shift back toward average or below average hydrologic conditions has meant higher water needs coupled with less water availability (Agrawala, 2001; "Drought", 2000; The International, 2001; Krutov and Lennaerts, 2000). This has heightened tensions among the basin states. Furthermore, the basin states overestimate their rightful share of water resources. When summed these exceed any reasonable estimate of the usable basin-wide resource (World Bank 1996, p. 15; ICAS, 1996, chapter 6).

On the other hand, the five basin states that were formerly part of the USSR have continued working in a cooperative spirit (through the ICWC) to annually share the waters of the Amu Dar'ya and Syr Dar'ya. Even during the recent drought, when substantial reductions in allocations were necessary, this process did not breakdown (MKVK, 2002a, pp. 9-18; 2002b, pp. 10-28). There was controversy and exceeding of water withdrawal limits by some states, but the most egregious violations were intrastate (particularly in Uzbekistan) as opposed to interstate. (Wegerich, 2001).

The Aral Sea's desiccation continues. Environmental and human related problems in the surrounding 'disaster zone' remain serious. Provision of sufficient inflow to stabilize or raise the level of the southern Large Sea in the south appears, at best, a distant hope. The water sharing agreement signed among the former republics of the USSR allocates water for preserving a remnant Amu Dar'ya delta and some minimal inflow to the sea proper. Even this modest goal is difficult to meet, particularly in dry years (MKVK, 2002a, p. 11-13; 2002b, pp.17-24).

The situation is not entirely bleak. At reasonable effort and cost, the level of the northern, Small Aral can be raised several meters and salinity lowered to a point where indigenous species would return from the Syr Dar'ya River and associated deltaic lakes, stimulating the partial restoration of the former commercial fishery (Micklin 2003). Such a project with a price tag of $84 million, funded by the World Bank, is underway. Also, the efforts underway since the late 1980s to stabilize, and in some cases improve, the ecological and human welfare situation in the Amu Dar'ya delta, for example, have made a positive difference and should be continued. There is even some hope for the Large Aral. The Amu Dar'ya could be redirected into the western, deeper section, freshening it and some ecological and economic value. However, this would entail complicated and expensive engineering may not be justified economically or environmentally[7]

The five Central Asian states deserve great credit for establishing regional institutions to deal with questions of basin wide concern. Although these institutions have not been able to satisfactorily resolve the most critical interstate water management conflicts or the fundamental problems related to the Aral Sea, they have focused attention on these and served as a forum for reasoned discussion of these matters as well as acting as a safety valve to diffuse tensions over water management issues among the states. The international donor community has provided valuable aid and assistance to these efforts.

Nevertheless, fundamental improvements need to be made in both the regional organizations and in the donor approach to providing assistance. Clarification of the responsibilities and functions of the regional agencies is of primary importance. IFAS (The International Fund for The Aral Sea) needs to receive more support from the five member countries in terms of financing, recognition of its interstate status, and supplying it with qualified personnel. Afghanistan must be included in negotiations on management of the Amu Dar'ya. Afghanistan provides about 8% of that river's flow and has the right under international water law to considerably increase its withdrawal from it.

International donors need to improve their operations. Of primary importance is improved cooperation among the major players (World Bank, U.S., European Union, and, more recently, the Asian Development Bank). Talk abounds of "working together", but this author's experience working in the donor community in Tashkent during the late 1990s suggests such rhetoric is more good intentions than reality. One means of promoting such a goal would be creation of a "Council of Donors" that would meet regularly to discuss the activities of the different donors, resolve disputes, and facilitate field-level coordination and cooperation. Implementation of donor aid programs needs to be accelerated. Expensive feasibility and planning studies drag on and on without tangible results that make a difference in the lives of the region's people..

Another problem is that the donor community may, inadvertently, be developing an "international welfare mentality" among the aid recipients in the Aral Sea Basin. Frequently regional, national, and local institutions in Central Asia approach international donors seeking funding for what are worthwhile endeavors but should really be funded from within the region. Often, it is not a case of lack of money but of governmental choices about spending priorities (e.g., precedence of grandiose public buildings and monuments in the capital cities over new hospitals, clinics, and drinking water supply facilities in the Aral Sea disaster zone). This is helped along by a pervasive attitude that the Aral Sea situation is a 'world problem' and that the international community has a moral and ethical obligation to help solve it.

Finally, what about the global importance of water and its management in the Aral Sea Basin? Should nations outside Central Asia and the international community be concerned? Environmental security is gaining increasing recognition as a force affecting national and regional stability. The desiccation of the Aral Sea is very serious for the people living near the sea but this issue little threat to the stability of the two states subject to substantial impacts (Kazahstan and Uzbekistan) for the simple

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[7] It might well make sense to let the Large Aral continue to dry and salinize. Brine shrimp (*Artemia*) have been discovered in the western part of the water body. When salinization here exceeds 100 g/l, which should occur in the near future, these organisms, whose eggs are a very high value fish food, should proliferate, possibly making commercial exploitation viable. A consortium of companies based in Belgium is investigating the commercial viability of Artemia in the Large Aral (Pala, 2003).

reason that the “disaster zone” around the sea constitutes a small portion of the territory of these nations and only minor parts of their populations live there. Furthermore, the sea and deltaic zones are in no way crucial to either country’s economy. Arguments that the ecological effects of the sea’s drying have any significant global environmental ramifications seem exaggerated.

On the other hand, management and sharing of the Amu Dar’ya and Syr Dar’ya could lead to serious problems as these rivers are vital to the five basin states that were formerly part of the USSR and to Afghanistan. As pointed out by Wolf (1998), disputes over water rarely lead to the much feared “water wars”. Of much greater concern for the Aral Sea Basin is that disputes over water interacting with other interstate, and frequently interrelated, issues such as ethnic clashes and boundary disputes could trigger isolated armed conflict leading, perhaps, to war (International, 2002).

There is reason for optimism. First, that the five former republics of the USSR, which control and use most of the water in the basin, have a long history of unified management of the resource and since independence have continued to cooperate bodes well for the future. Secondly, rationality argues for the basin states to continue cooperation and compromise in managing and sharing their transnational water resources as this will benefit all stakeholders. Thirdly, there is real hope that strengthened regional water mangement organizations in concert with the international donor community can substantially improve the interstate water sharing agreements and bring them more into line with international water law, which is fundamentally based on the principle of “equitable and reasonable use” (Wouters 2000; Corriia, 1999). Such an accomplishment would greatly ease interstate tensions. However, this would require allocating more water to upstream Kyrgyzstan and Tajikistan, substantially reducing irrigation water use to make this possible, and bringing Afghanistan into the water sharing agreement.

Uzbekistan is critical. As the most populous, militarily and politically powerful, economically developed, geographically strategic and heaviest irrigating state in the basin, the course it follows will likely have the determinant influence on the success, or lack thereof, of cooperative management of transnational waters. If this state focuses excessively on aggressive, national self-interest in water management, as it has been wont to do in the past, efforts towards the more effective management of national and transnational water resources will founder and peaceful relations among basin states will be placed in jeopardy.

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=========================== **ДОКЛАДЫ** ===================================

ДИНАМИКА ФЕНОЛОГИИ РАСТИТЕЛЬНОГО ПОКРОВА В УЗБЕКИСТАНЕ И ТУРКМЕНИСТАНЕ

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Центр передовых информационных технологий управления земельными ресурсами (CALMIT), Школа природных ресурсов. Университет Небраска-Линкольн, 102 E, Небраска Холл, Линкольн NE, 68588-051 7, США

Землепользование является фактором существенно влияющим на фенологию растительного покрова. Мы использовали нормализованный индекс, NDVI, который мы вычислили используя космические данные, полученные AVHRR/NOAA - так называемый PAL-база данных.

Мы пытаемся ответить на вопрос: как изменения в растительном покрове связаны с изменениями в государственном устройстве и землепользовании, унаследованные после распада СССР. Мы изучали изменения в фенологии растительности в шести пустынных и трех поливных регионах Узбекистана и Туркменистана. Мы использовали различные статистические методы - многократное сравнение, - Манн-Кендак Тренд, который включает коррекцию автокорреляцию и другие методы. Многократные сравнения для пустынь выявило аномальное поведение индексов, полученных из данных NOAA-11. Данные NOAA-9 и NOAA-14 сравнивались для всех регионов кроме одного региона в Узбекистане, расположенного на юго-западе от Аральского моря.

Кроме значительного тренда NDVI, найденного в NOAA-11, только в одном регионе был найден значительный тренд в NDVI, полученном из NOAA-14. Тренды в индексах существенно различаются. Квадратичная модель работала весьма точно для Казахстана в 90-х годах. Мы обнаружили существенное увеличение индекса в 90-х годах в начале сезона в сравнении с его величиной в 80-х в Казахстане. Это увеличение подобно найденному в Казахстане, но здесь оно менее выражено и не столь убедительно.

Квадратичная модель не объясняет поведения фенологии растительного покрова в двух других поливных регионах (бассейн реки Зерафшан в южном Узбекистане и Каракумский канал в Туркменистане). Фенология изменилась так существенно, что описание этих изменений требует не квадратичной, а линейной модели.

Наша интерпретация изменений, которые были выявлены при использовании космических данных, соответствует нашим предыдущим результатам, полученным для среднеазиатских стран, включая Казахстан.

LAND SURFACE PHENOLOGIES OF UZBEKISTAN AND TURKMENISTAN BETWEEN 1982 AND 1999

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Center for Advanced Land Management Information Technologies (CALMIT),
School of Natural Resources, University of Nebraska-Lincoln,
102 E. Nebraska Hall, Lincoln, NE, 68588-0517 USA
1Corresponding author: ghenebry@calmit.unl.edu; +1-402-472-6158 (-4608 FAX)

Introduction

Satellite image time series enable remote synoptic monitoring of the planetary surface. A multitude of orbital sensors currently observe the Earth across a variety of wavelengths and spatio-temporal resolutions. Which kind of imagery is better suited for a particular job depends strongly on the question to be addressed. Here we are interested in changes in land surface phenology in Turkmenistan and Uzbekistan. Let us define land surface phenology as the spatio-temporal development of vegetated land surface as revealed by synoptic radiometers. Directional climate change might induce changes land surface phenology of a region resulting in such phenomena as earlier onset of spring or senescence

(Myneni et al., 1997, Zhou et al., 2003). However, land surface phenology can also change as a result of shifts in land cover composition or alterations in land management practices. When analyzing for change in land surface phenology, the temporal resolution of the imagery is relatively more important than the spatial resolution. Long image time series from sensors with high repeat frequencies (1-3 days) are well suited for the change analysis of land surface phenology despite their relatively low spatial resolution (250 m – 8 km).

The Advanced Very High Resolution Radiometers (AVHRR) on a series of NOAA (National Oceanographic and Atmospheric Administration) Polar Orbiting Environmental Satellites have produced observational datastreams with global extent and high temporal frequency. The Pathfinder AVHRR Land (PAL) dataset is a widely-available standard processing of these AVHRR data into 10-day maximum Normalized Difference Vegetation Index (NDVI) composite image time series extending from mid-1981 through 2001. Previously, we have reported several problems with this dataset that could obscure the conclusions from simple change analyses (de Beurs and Henebry, 2004b). In addition, we demonstrated how to avoid detecting spurious trends and identified which portions of the dataset can be validly compared.

In a comparable study in Kazakhstan we have shown that there were significant changes in land surface phenology after institutional change, especially in agricultural regions (de Beurs and Henebry, 2004a). Here we will apply the same analytical approach to PAL NDVI data from

Turkmenistan and Uzbekistan between 1982 and 1999. First, we will demonstrate that the sensor artifact as we have observed over other deserts of Central Asia is also visible in the deserts of Turkmenistan and Uzbekistan. Second, we will analyze the remaining sections of the image time series in order to understand the influence of the institutional change that occurred in these two countries after the collapse of the Soviet Union in 1991. We will focus on both desert regions and irrigated agricultural areas.

Data

AVHRR NDVI data have been frequently used to analyze for changes in greenness or land surface phenology (Myneni et al., 1997, Zhou et al., 2001, Zeng et al., 2003). Data from the AVHRRs on four platforms—NOAA-7 (1981-1984), NOAA-9 (1985-1988), NOAA-11 (1989-1994), and NOAA-14 (1995-1999)—constitute the PAL NDVI dataset from 1981 through 1999. Deserts have been commonly chosen as vicarious calibration targets to correct sensor data through time. Since the interannual variability of NDVI in deserts is relatively low; significant variation in the data over desert regions is inferred to result from sensor artifacts (Rao and Chen, 1995, Rao and Chen, 1996). The Libyan Desert has been used as a vicarious calibration site for the PAL NDVI data (Rao and Chen, 1995, Rao and Chen, 1999). The data have been corrected for changes in sensor calibration, ozone absorption, Raleigh scattering, sensor degradation after pre-launch calibration, and have been normalized for differences in the solar zenith angle at image acquisition (Kaufmann et al., 2000). However, no stratospheric aerosol corrections for the volcanic eruptions of El Chichón (1982-1984) or Mt. Pinatubo (1991-1993) were performed.

For this study we selected the last 10-day compositing period in April through the last compositing period in September from 1982 through 1999. Figure 1 provides an overview of the average NDVI from Uzbekistan and Turkmenistan calculated from all image composites between 1982 and 1999. In contrast to convention, the darker areas shown here indicate higher average NDVI, while the lighter areas indicate lower NDVI. The Aral Sea is located in the north of Uzbekistan and Turkmenistan borders the Caspian Sea in the West. The darker areas in the south east part of Uzbekistan are mountainous areas with higher NDVI than the other regions. Along the Amu Darya toward the Aral Sea there are large irrigated regions, mainly cultivated with cotton and wheat. There is also irrigation along the Zerafshan River in the south of Uzbekistan. Other irrigated regions can be found in the south of Turkmenistan, along the

Karakum Canal. We selected a subset for analyses in each of these irrigated regions (not shown). In the brighter desert areas, we selected 6 relatively homogeneous regions, three in Uzbekistan (UZ1-

UZ3), and three in Turkmenistan (TK4-TK6). By averaging the NDVI for a study region, we generated a NDVI time series for each region. .

Figure 1: Location of study areas overlaid on regional map of average NDVI. Note that the scaling of the NDVI is reversed: higher (lower) NDVI values are darker (lighter) in tone. Three regions (UZ1-UZ3) are located in Uzbekistan and three regions (TK4-TK6) in Turkmenistan.

Methods

We apply three different, but complementing methods in order to analyze the image time series for this study.

Discontinuities

Since the data is recorded by four satellites it is important that the transition from one satellite to the next is smooth and without steps. However, the data from each satellite is calibrated separately. Thus, discontinuities or sometimes called step changes, from one satellite to the next could influence the total data record and could be mistaken for changes on the land surface. To investigate discontinuities in the image time series over the deserts of Uzbekistan and Turkmenistan, we compare the average NDVI from all four sensors simultaneously. It is important to realize that most standard methods to compare group averages fail when basic assumptions are not met, such as normality of the data, equal variance among groups, and equal numbers of observations within groups (Dunnet, 1980, Day and Quinn, 1989). Therefore, we use the C-method for normally distributed data and the Fligner-Policello test for non-normal data. Both tests are corrected for inequalities in variances and in observations. We apply the same routine to the growing degree day data.

Trends

The next step is to determine if there are any significant trends within the time series of an individual satellite. Trends within sensor periods over the desert usually point to sensor artifacts. Unfortunately linear regression to estimate a trend from a time series of observations is still a practice widespread in the remote sensing literature. However, there are many assumptions that are violated when this method is applied to the PAL NDVI data. The seasonal Mann-Kendall (MK) trend test is an alternative method that avoids these statistical pitfalls and uses all available observations. This is a nonparametric test corrected for autocorrelation that is routinely used in the analyses of meteorological time series (Dietz and Killeen, 1981, Hirsch and Slack, 1984, von Storch and Navarra, 1999). We also subject the growing degree-day data to the MK trend test.

Changes in land surface phenology

In the last step of this analysis, we are interested in changes in land surface phenology in irrigated regions before and after institutional change. We have previously shown that simple quadratic regression models that describe NDVI as a quadratic function of accumulated growing degree-days (AGDD) with a base of 0° C offer a parsimonious model for the land surface phenology of agricultural regions in Kazakhstan (de Beurs and Henebry, 2004a).

In this analysis we follow the same approach and fit the following model to the data from NOAA-9 and NOAA-14, separately:

NOAA-9 and NOAA-14, separately:

$$NDVI = \alpha + \beta AGDD + \gamma AGDD^2 \quad (1)$$

AGDD are calculated as follows:

$$AGDD = \sum_{t=01Jan}^{31Dec} GDD_t, \quad \text{if } GDD_t > 0^\circ C \quad (2)$$

$$GDD_t = \frac{(T_{max} + T_{min})}{2} \quad (3)$$

We have chosen to restrict our attention to data from NOAA-9 and NOAA-14. These sensors span four and five year periods, respectively, on either side of the institutional change in 1991. The comparison of data from these two satellites is not affected by sensor artifacts (de Beurs and Henebry, 2004b). The a-parameter in the model gives the intercept, the NDVI value that is found for low AGDD. The P-parameter is the linear parameter and controls the green-up rate. The y-parameter determines the width of the quadratic model; it is a measure of the length of the growing season. The p- and y-parameters together determine the amount of AGDD required to reach maximum NDVI and the start and the end of the observed growing season.

Results Discontinuities

Most selected regions followed a log-normal distribution and thus we applied a log-transformation to the data. We then applied the C-method for multiple comparisons with a nominal a-level of 0.05. Given that the NOAA-11 AVHRR failed September 1994, it was likely suboptimal during the preceding months; thus, we decided to exclude all 1994 composites from our analysis. Figure 2 gives the boxplot for UZ1, the study region with the lowest NDVI. The data from the AVHRR on NOAA-11 are significantly higher compared to the NDVI values from

the other AVHRRs. There is also a significant difference between NOAA-9 and NOAA-14. However, there are no significant differences between the other two combinations of satellites (NOAA7 vs. NOAA9, NOAA7 vs. NOAA14).

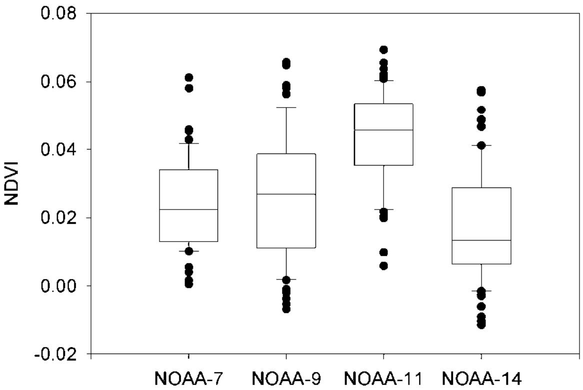

Figure 2: Box-plot for UZ1 the desert ecoregion with the lowest NDVI. The mean NDVI during the NOAA-11 period is significantly higher than the mean NDVI observed during the other satellite

periods. The mean NDVI during the NOAA-14 period is significantly lower than the mean NDVI during the NOAA-9 period.

The remaining results from the other study regions can be found in Table 1. The study regions are ordered from lowest to highest average NDVI value. Most study regions show only significant differences for the comparisons between NOAA-11 and the other satellites. TK5 only shows a significant difference between NOAA-11 and NOAA-14. We did not find a significant difference in AGDD (°C) for any of the comparisons (data not shown).

Table 1: Multiple Comparisons, data from 1994 is excluded.

	7-9	7-11	7-14	9-11	9-14	11-14
UZ1		**		**	**	**
TK4		**		**		**
UZ2		**		**		**
TK5						**
UZ3		**		**		**
TK6		**		**		**

Significant difference at α = 0.05

Trends

The seasonal Mann-Kendall test was applied to the original NDVI data from all study regions. Since this test does not require normality, the data were not log-transformed. The satellite periods with p-values below 0.05 are considered to have a significant trend. Even though all composites from 1994, which is known to be a problematic year, have been excluded a significant trend is observed in all study regions for NOAA-11. Except TK5, no study region shows a significant trend for any other satellite. TK5 displays a significant trend during NOAA-14 (1995-1999).

Table 2: p-values for the seasonal Mann-Kendall trend test for NDVI and AGDD (˚C) (data from 1994 is excluded).

	NDVI				AGDD (°C)			
	7	9	11	14	7	9	11	14
UZ1	0.42	0.38	0.02	0.27	0.04	0.50	0.01	0.13
TK4	0.25	0.11	< 0.01	0.12	0.05	0.37	0.05	0.26
UZ2	0.13	0.18	0.01	0.08	0.05	0.30	0.09	0.34
TK5	0.18	0.16	< 0.01	0.03	0.11	0.21	0.07	0.32
UZ3	0.35	0.22	0.02	0.12	0.11	0.50	0.30	0.48
TK6	0.33	0.23	0.02	0.44	0.08	0.18	0.03	0.08

p-values < 0.05 (in bold) are considered significant

Figure 3a gives the NDVI time series from TK5. NDVI varies from 0.00 to about 0.08. In the last 10-day period of July 1983 NDVI reaches a very low point (0.00045). Furthermore, there is a significant trend visible in NOAA-11. NOAA-14 shows a significant trend that starts at the beginning of 1996 and increases until 1998. This trend is long enough to influence the overall trend captured in the time series and results in a p-value for the Mann-Kendall trend test less than 0.05. Figure 3b shows the coefficient of variation for NDVI from the same region. The region consists of an area of 25,664 km2, containing

401 image pixels. The coefficient of variation is calculated as the standard deviation over all pixels divided by the mean of the pixels and its time series gives an indication of spatio-temporal variation within the region. Figure 3b clearly shows that the inter-regional variation is much higher in NOAA-9 than in the other regions, and the

variation is lowest for NOAA-11. We find a similar but less pronounced pattern in UZ2. This pattern is absent in the other regions, where there is no significant difference in the variability between satellite periods. We find significant positive trends in the growing degree-days for UZ1, TK4, and UZ2 in NOAA-7 and we find negative trends in the growing degree-days for UZ1, TK4, and TK6 in NOAA-11 (Table 2).

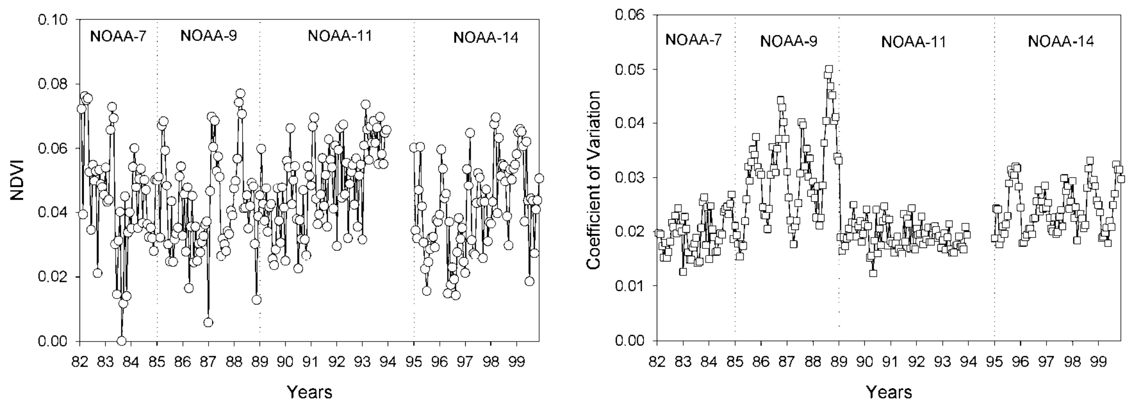

Figure 3: (a) NDVI signal from TK5. There is a clear positive trend visible in the data from NOAA-11. (b) Coefficient of variation of NDVI from TK5.

Land surface phenology change

Figure 4(a-c) give the phenological models as captured in three irrigated regions in the study area. Figure 4a gives the phenological models before (1985-1988) and after (1995-1999) institutional change in the irrigated region in Karakalpakstan just south of the Aral Sea in Uzbekistan. These models strongly follow a quadratic curve during the growing season, with low average NDVI for low growing degree-days in the last part of April until a peak NDVI around 3500 AGDD after which the NDVI decreases again. The models for both periods exhibit very good fits (R2 > 0.90) and the interannual variation is relatively low. The intercept of the model is significantly higher after institutional change, the increase is about 30%; however, neither the linear nor the quadratic parameter changed. This indicates that the peak of the growing season is reached in the same amount of growing degree days after institutional change, and the length of the growing season did not change either. Although, the intercept is higher, figure 4a demonstrates that the models are fairly similar. We found a similar result in an irrigated area of Kazakhstan along the Syr Darya. Figure 4b gives the phenological models for an irrigated region along the Zerafshan River in southern Uzbekistan. The phenological pattern changes drastically after institutional change, going from a well-fitting quadratic model (R2 = 0.75) to a linear model (R2 = 0.70). Most of this change is the result of a double peak NDVI in the years 1997 through 1999. These years show a small peak around 1000 AGDD after which they reach a local minimum NDVI around 1800 AGDD. The second peak occurs at about 3900 AGDD. Figure 4c gives the phenological models for the large irrigated region along the Karakum Canal in Turkmenistan. This last region shows a similar pattern as in Figure 4b, the quadratic model fits reasonably well before institutional change (R2 = 0.75), but in the second period the fit declined drastically (R2 = 0.16). Again, there is a double peak for 1998, however, during 1999 the NDVI does not really show a clear growing season, but is almost equally high during the entire year.

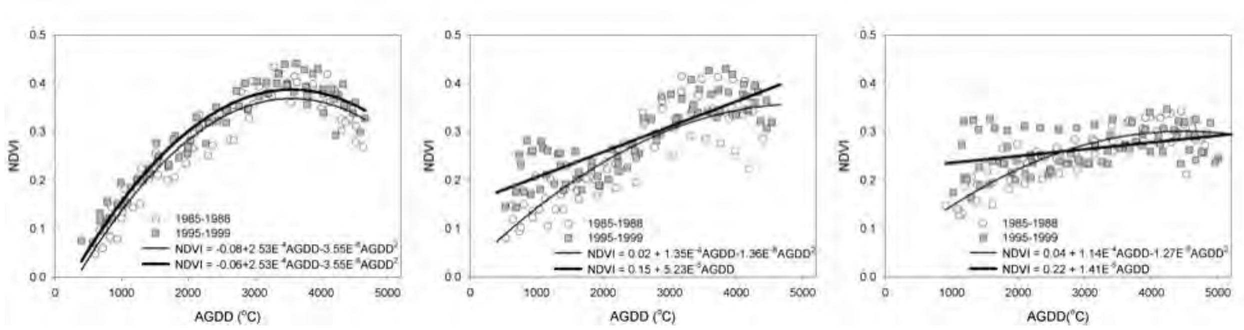

Figure 4: (a) Quadratic models from the irrigated region in Karakalpakstan just south of the Aral Sea, (b) models for the irrigated region along the Zerafshan River in southern Uzbekistan and (c) models for the irrigated region along the Karakum Canal in Turkmenistan. The white dots are from NOAA-9 (1985-1988); the grey squares are from NOAA-14 (1995-1999). The thin line fits the data from NOAA-9 and the thick line fits the data from NOAA-14.

Discussion and Conclusion

We applied three different analyses to determine changes recorded by the PAL NDVI dataset. First, we compared the average NDVI from all four satellite periods in six desert regions. We found that the average NDVI from NOAA-11 was significantly higher than that of the other satellites in almost all desert regions. We also applied the C-method to the growing degree-days from the same periods and found no significant difference. We conclude that the increase in NDVI during NOAA-11 is not a result of a change in temperature. This corresponds with our previous results for more than 2 million km2 of desert ecoregion in Central Asia (de Beurs and Henebry, 2004b). Apart from the different behavior of NOAA-11, we found a significant

decrease from NOAA-9 to NOAA-14 in UZ1. This region is located relatively close to the Aral Sea which may cause negative NDVI values to influence the average.

Second, we tested the NDVI time series from each satellite separately for significant trends. Again, NOAA-11 shows a different behavior than the other satellites with positive trends in all selected regions. This corresponds with the results that we found in other desert regions in the surrounding countries. Even though we find a slight negative trend in the growing degree-days in three regions during NOAA-11, we conclude that the positive NDVI trend is a result of sensor artifacts in NOAA-11. While the trend in growing degree-days is significant, it is not very dramatic and it was not observed in all the desert regions. Furthermore, the trend is not continued during NOAA-14. The only region that shows a significant trend other than the one reported in NOAA-11 is TK5. This region shows a significant trend in NOAA-14 as well. Also, the coefficient of variation is changing for this region. This region is the most southerly region, close to the irrigated areas of Turkmenistan. We speculate that the NDVI signal for this region has been contaminated by high NDVI from the irrigated areas in the vicinity due to poor co-registration.

Lastly, we fitted quadratic regression models to the data from the irrigated regions in Uzbekistan and Turkmenistan. The three regions show very different behaviors and the model fits best for the irrigated region just south of the Aral Sea. After institutional change we find a slight increase in the intercept parameter, while the linear and quadratic parameters do not change. This corresponds to our findings in the irrigated regions in Kazakhstan, although there the increase in intercept was much more substantial (de Beurs and Henebry, 2004a). While for Kazakhstan we concluded that the increase in intercept was likely a result of improved efficiency in production after institutional change, we are hesitant to make the same conclusion for this region in Uzbekistan. The models fit extremely well in both periods; thus, small deviations in particular data could work as leverage points. Since the increase in intercept is rather small, we conclude that small outliers could have caused this difference. The models for the irrigated regions in southern Uzbekistan and in Turkmenistan change drastically following institutional change. We observe distinct bimodal behavior in Uzbekistan from 1997 through 1999. This could point to a change in crops or land cover. The irrigated region in Turkmenistan after institutional change is highly influenced by the very high average NDVI in 1999. Turkmenistan experienced record high grain yields in 1999 mostly due to better incentives and seed and

fertilizer use (FAO, 1999). This increase could possible explain the overall high NDVI during this year.

Overall, we conclude that the presented methods are capable of analyzing the interannual variability that is captured in the PAL NDVI data. It is possible to pull apart several sources of variation that influence the NDVI signals. The results for Uzbekistan and Turkmenistan are comparable to previous findings in other Central Asian countries including Kazakhstan. However, especially in the case of Turkmenistan, the results require a different interpretation.

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============================ ДОКЛАДЫ ====================================

ОСНОВНЫЕ ФАКТОРЫ ИЗМЕНЕНИЯ КЛИМАТА И ОКРУЖАЮЩЕЙ СРЕДЫ В СРЕДНЕЙ АЗИИ

© 2005 г. М.Г. Насыров

Кафедра физиологии растений и микробиологии,
Самаркандский государственный университет,
703008 Самарканд, ул. Катта-Курганская 1, Узбекистан

Возрастание численности населения, опережающий рост его потребностей, неуклонное расширение использования ресурсов региона, внедрение новых технологий и возрастание производства в энергетике, промышленности, сельском хозяйстве, транспорте, антропогенное преобразование ландшафтов, усложнение и расширение межгосударственных связей, - все эти и многие другие факторы привели к возрастающей антропогенной нагрузке на окружающую среду, с усилением взаимодействия между средой и обществом.

Заключения группы экспертов 1PCC(Межправительственная комиссия по изменению климата) показывают, что эти изменения нельзя объяснять только естественными явлениями и что имеется ясное свидетельство интенсивного человеческого влияния на ход природных процессов.

Вопрос не в том, действительно ли климат изменяется, а в том, на, сколько будет он изменяться, и как скоро и где будут изменения самыми большими. В этом вопросе есть и противоречивые суждения.

Подсчитано, что приблизительно 50-100 тысяч миллионов тонн углерода атмосферы может быть поглощено за счет превращения их в органическое вещество почв и 100-150 тысяч миллиона тонн от фотосинтетической деятельности растений. Однако, объективный характер и природа этих процессов еще не ясен, и во всей вероятности, это не будет одинаковым в различных экосистемах.

В связи с этим, необходимо провести инвентаризацию выброса парниковых газов в основных сферах деятельности человека. Инвентаризация должна проводится с использованием новых инструментальных методов, позволяющих получить истинную картину происходящего в сравнительно короткое время и на достаточно больших площадях.

Анализ многолетних результатов инструментальных измерений динамики продукционного процесса показал что полынно-эфемеровые пастбища Средней Азии имеют потенциал извлекать из атмосферы и переводить в биомассу около 690 г CO^2 на квадратный метр в год. На основе многолетних исследований так же удалось выявить буферную роль этих пастбищ как основного поглотителя избыточной концентрации $CO2$ в атмосфере.

Инструментальные исследования продуктивности доминантной растительности пастбищ Средней Азии имеют большое научное и практическое значение и могут быть успешно применены для качественной и мобильной оценки их экологического состояния в условиях изменяющегося климата.

THE MAIN DRIVERS OF CLIMATE AND ENVIRONMENTAL CHANGE IN CENTRAL ASIA

© 2005. M. G. Nasyrov
Plant physiology and microbiology
Samarkand State University,
703008 Samarkand, Katta-Kurganskaya 1, Uzbekistan

INTRODUCTION

The continuous increase of desertification and degradation in semi-arid lands in Central Asia is the results of rapid population growth, the availability of modern techniques and technologies for land cultivation, as well as the loss of traditional habits and changes in traditional land use.

These major factors are additionally influenced by recent political and economic changes and collapse of the former USSR, lack of awareness among concerned parties, and the non-availability of information about current situation in the affected areas.

Although recent concern for the global environment has tended to highlight threats posed by global warming and climate change, soil erosion and associated land degradation undoubtedly remain serious problems in Central Asia.

Population growth and associated expansion and intensification of agricultural activity in many areas of the Central Asia have caused increased rates of land degradation. The region faces a serious challenge to its natural resource base. Croplands, rangelands and mountains are getting degraded. The reduced availability of agricultural inputs, and feed and fodder is resulting in a decline in livestock numbers. Water scarcity and misuse is compounding the threat to food security, human health, and ecosystems.

In order to solve these problems an integrated approach is required to identify and implement new environmentally friendly and economically sustainable agrotechnologies that deals with all the above mentioned issues.

THE PHYSICO-GEOGRAPHICAL AND ECOLOGICAL DESCRIPTION OF THE REGION

Central Asia occupies a unique place on the geographical map of the world. Being located in the center of the Eurasian continent, it is, literally and figuratively, located on the crossing of axis “North-South” and “West-East”. This peculiarity of geographical location has a large influence on the cultural, political, economic, social, and ecological life of the region.

From the earliest times, the Great Silk Road, connecting the countries of East with European countries, has played the role of cultural, trade-economic transcontinental link. Ancient culture, woven of traditions and customs of many peoples, formed colorful modern face of Central Asia.

The basis of life here has always been land cultivation and cattle breeding, and water has been the main constraining factor. The beginning of active irrigated land cultivation in the region dates back to 6th-7th centuries B.C. and coincided with the highest prosperity of ancient civilization, where irrigation had always been the main decisive factor of historical and social development

The regional ecosystems are very sensitive to anthropogenic influence in connection with arid conditions. An extensive method of household operation in previous years has contributed to appearance of numerous regional ecological problems, to include one of the biggest ecological disasters on Earth, namely the Aral Sea tragedy. This region covers an enormous area of 418 million ha, of which about 275 million ha are classified as rangelands (Beniwal et al., 2000).

The most common ways of rangeland utilization are grazing, firewood and medicinal plant collection, and converting them into croplands (e.g., barley, spring wheat, and vegetables).

MAIN DRIVERS OF CLIMATE AND ENVIRONMENTAL CHANGE

The world as well as Central Asia is changing rapidly. There are several basic drivers of climate and environmental change such as population and economic growth, urbanization, human investment patterns, family structure and education, social stability, land use/land cover change, etc.

Population growth is the main problem of environmental change. By the end of 19TH century, there were some 7-8 million people in the region. Irrigated land amounted to about 3.4 million hectares and was equipped by an irrigated network. By 2000, the regional population had increased by 7 times, and irrigated areas have increased two-fold up to 7.5-7.7 million hectares.

Population growth is also one of the main reasons of natural resource decline in the region. Annual population growth in Kyrgyzstan is 1.5%, in Tajikistan, 2.5%, in Turkmenistan, 2.4%, and in Uzbekistan, 2.3%.

Although slowing, population growth is still rising and the highest rates are in those countries, which are least able to sustain them.

CURRENT SITUATION NEAR ARAL SEA

The Aral Sea, once the world's fourth biggest inland sea, has declined from a volume of about 1,000 km3 40 years ago to 110 km3 today. The water level fell within that time from 53m to 28 meters. The annual inflow in 1960 was 63-65 km3, but now it is a mere 1.5 km3. Yet 10 km3 of inflow are needed just to keep the sea as it was, let alone to reverse its plight. The mineral content of the water is now up to seven times higher than 40 years ago, with pesticides and fertilisers combining with salt to produce "a sort of salty paste". The shoreline receded by up to 250 km, leaving toxic dry deposits. Dust blown away by the wind cause serious threats to human health. Anemia, cancer, liver and kidney diseases and children's illnesses are all increasing.

The devastation of Aral Sea dates from the Soviet era, when huge tracts of Central Asia were turned into chemically intensive cotton farming. Poorly efficient irrigation systems still consume huge amounts of water that would once have reached the sea. The Syrdarya, which flows into Northern section through Kazakhstan, provides almost all the inflow to the entire Aral. The more Southern Amudarya contributes little more than a trickle.

All Central Asian countries share Aral waters and have formed the International Fund for Saving the Aral Sea (IFAS). Afghanistan has proposed to join IFAS, since 10% of the Amudarya's flow comes from that country.

Overgrazing of the rangelands by livestock is believed to be the most widespread cause of degradation in the region. Overgrazing around settlements is often related to the sedentarization of nomadic herders. The settlement of the former nomads means that their herders would be concentrated onto grazing around their homes.

Under drought conditions, these herders are forced to concentrate their animals in areas where drinking water is available, causing the complete disappearance of the most palatable herbaceous cover in many places, particularly around boreholes that provide drinking water for humans and their animals all year round.

The recent privatization processes in the agricultural sector led to changes in land use, crop yield and livestock numbers. During the Soviet era, the Central Asian republics were provided with wheat from Russia, the Ukraine and Kazakhstan to augment what they were producing locally. Each country had to plant a specialized mandated crop.

In Uzbekistan, cotton, was the major crop and was exchanged for staple foods. After the collapse of the Soviet system, the new republics had to produce their own food, mainly under rainfed conditions. Increasing wheat production had to be achieved by increasing yields and acreage given over to wheat production, both on irrigated and rainfed land. Some of the cotton-irrigated area also was re-assigned to wheat grain production.

Barley cropping on rainfed areas changed gradually. The barley overall yield decreased slowly over the years by approximately 60 kg/ha/year. This may indicate that not only were the rainfall season poor at the end of the 1990s, but also that barley cropping was relegated to the lower rainfall zones and on to the poorest soils, hence the slow observed decrease in production. It is also quite probable that some of barley production areas and also new rainfed cropping areas brought into cultivation through range clearing were assigned to wheat production. This was at the expense of the best rangelands in the best rainfall zones on the adyr (Uzbek native word?) and also in the pre-desert areas where extra run-off could be secured (Gintzburger et al.,2003)

THE POTENTIAL OF VARIOUS ECOSYSTEMS FOR SEQUESTERING CARBON

Degradation of rangelands reduces their capacity to assimilate carbon dioxide (CO2) from the atmosphere by their vegetation for photosynthesis, and thus contributes to global warming. Rational management and improvement of these rangelands will not only increase their productivity to satisfy the growing need for feed for livestock, but will also allow them to act as a sink for CO2 and help in reducing the global warming.

According to the latest IPCC estimates, rangelands may play an important role in sequestering atmospheric CO2 (Allen-Diaz et al., 1996). Based on research concerning organic matter, especially if conditions and productivity of overgrazed and desertified areas could be improved through effective management (Gilmanov, 1995,1997).

Various landscapes have been hypothesized as potential contributors to the “missing sink” including rangelands. The vast areas of grazing lands are believed to have a large potential to sequester carbon and mitigate the greenhouse effect. Although arid and semi-arid ecosystems are known to have substantially lower productivity than forests, it was hypothesized that the vast landscapes of Central Asia dominated by rangeland ecosystem could be an important contributor to the “missing sink”(Nasyrov, 2000). Thus, the main objective of the special project was (GL-CRSP, Livestock Development and Rangeland Conservation tools for Central Asia) to document the daily magnitudes and growing season dynamics of net ecosystem CO2 exchange (NEE) in representative rangelands of Kazakhstan, Uzbekistan, and Turkmenistan.

However, direct field measurements of the magnitude and dynamics of CO2 fluxes on rangelands of Central Asia have not been made. Therefore, a project that gathered interdisciplinary team of scientists from different international and national institutions included experimental measurements and mathematical modeling of net CO2 fluxes at three representative rangeland sites of Central Asia was initiated in 1998.

Continuous measurements of the diurnal and seasonal dynamics of CO2 exchange were obtained at three sites in Central Asia. Field stations, such as the Bowen Ratio/Energy Balance (CO2/BREB) system manufactured by Campbell Scientific (Model 023) for the measurement of CO2 flux, energy balance, and related micro-meteorological characteristics, were established at the beginning of the 1998 growing season at three sites, which characterized representative rangelands of Central Asia. These included: typical steppe, Shortandy site, Kazakhstan; sagebrush-ephemeroidal semidesert, Karnap site, Uzbekistan; and shrub sandy desert, Karrykul site, Turkmenistan.

The main aim of the project was to determine the role of rangelands of Central Asia in the global carbon cycle, and to test the utility of carbon dioxide flux technology for assessing the productivity of the various rangeland ecosystems. Flux refers to the net movement of CO2 back and forth between the surface (soil and plants) and the atmosphere.

Field data for CO2 fluxes and associated micro-meteorological characteristics were collected continuously at 20-minute intervals. These data were routinely transferred electronically to Nickanor Z.Saliendra of the Forage and Range Research lab, United States Department of Agriculture-Agricultural Research Service (USDA-ARS), Logan, Utah, for processing into five-day segments.

The segmented data sets were subsequently used to calculate daily integrals of CO2 flux. These data were analyzed by T.G. Gilmanov at South Dakota State University to evaluate the relationships between micro-meteorological characteristics and rates of CO2 flux.

The obtained results indicated that net growing season CO2 fluxes were positive at all three rangeland monitoring sites in Central Asia with a daily and seasonal flux as for the typical steppe of northern Kazakhstan sequestered 328 g CO2/m2/season, which is equivalent to 89 g C/m2. The sagebrush-ephemeroidal semidesert site at Karnap, Uzbekistan sequestered 698 g CO2/m2/season. The shrub sandy desert at Karrykul in Turkmenistan sequestered 175 g CO2/m2/season.

Given the vast area of rangelands, this rate of carbon assimilation can turn Central Asian rangelands into a significant CO2 storage sink, and they can greatly contribute to reducing the global warming trend. This makes the rehabilitation and management of Central Asian rangelands all the more important. As a result, rangelands in Central Asia appear to play an important role in the sequestration of carbon.

Several years of field and laboratory experiments have shown the suitability of Bowen Ratio techniques for rangeland conditions in Central Asia.

In addition to these results, the project also provided a spin-off in terms of the human resource development. Scientists from all the measurement sites in Central Asia are now able to maintain and fully operate the Bowen Ratio system and could be considered as capable partners for future joint international projects in Central Asia.

FURTHER STEPS….

As a matter of course, the serious problems raised by environmental management and regional sustainable development lie eventually in the hands of policy makers. Their action must be based on a sound physical and socio-economic scientific expertise, which requires both a disciplinary and interdisciplinary approach within an integrated environmental scope, the so-called IEA “Integrated Environmental Assessment.”

In order to contribute to food security, poverty alleviation, and environmental protection in Central Asian region and other drylands region one needs to:

Increase production, household income and welfare

Conserve or arrest degradation of natural resources

Assess current status of agroecosystems and combined impact of technologies on ecological changes and the efficiency with which resources are used for increasing human living standard at the levels of farm and collection of farms, village and a landscape.

Site assessments should take into account a broad range of information that can help to understand processes of change and the actors that participate in these changes. A variety of ethnoscientific methods can be employed, including the reconstruction of landscape histories and interviewing of knowledgeable villagers.

The GIS and modeling methodologies are also the only available way to integrate vast amounts of available data on drylands (soil, vegetation, climate, population) with new approaches to provide managers and decision-makers at the local and regional scales an adequate tool to increase the productivity and ensure the sustainability of drylands to satisfy the needs of the human population of the region.

The results of this assessment will help scientists understand trends in local biodiversity degradation and will provide ideas for their better management, and will also help identify particularly dynamic, resourceful, and resilient components of the village.

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============================ **ДОКЛАДЫ** ====================================

ПРИРОДНЫЕ И СОЦИАЛЬНЫЕ АСПЕКТЫ РАДИО - ЭКОЛОГИЧЕСКОЙ СИТУАЦИИ В КАЗАХСТАНЕ

© 2005 г. [1] А.Н. Ермилов, [2] Е.В. Ермилова

[1]Институт Ядерной Физики НЯЦ РК
[2] Казахский национальный университет Аль-Фараби,
480012, Алматы, ул. Карассой Батыра 95а, Казахстан

В статье представлен обзор сложившейся в Казахстане радиоэкологической ситуации, а также описание ядерных и радиационных факторов, имеющих влияние на окружающую среду, названы природные и техногенные факторы, определяющие уровень радионуклидного загрязнения окружающей среды, и обсуждается возрастающая роль радиоактивности как фактора окружающей среды человека. Ни в одной другой стране мира вопросы, связанные с радиоэкологией не приобрели такой остроты, как это имеет место в Казахстане. Масштабы радиоэкологических проблем и их разнообразие выводят их в один ряд с первостепенными экологическими проблемами региона такими как вопросы воды и хозяйственной деятельности человека. Кратко обсуждаются некоторые социальные вопросы и проблемы жизнедеятельности человека на территориях со сложной радиационной обстановкой, делается утверждение о том, что человечеству придется искать пути выживания в условиях повышенного радиационного фона. .

ENVIRONMENTAL AND HUMAN DIMENSIONS OF RADIO-ECOLOGICAL SITUATION IN KAZAKHSTAN

© 2005. [1]Yermilov A.N., [2]Yermilova Ye.V.

[1] Institute of Nuclear Physics of National Nuclear Center, Kazakhstan
[2] International Academy of Business, Almaty, Kazakhstan

Introduction

Kazakhstan is a land of 5 nuclear test sites where about 500 nuclear explosions were performed by USSR; this land is very rich in uranium ore, has a well-developed uranium industry, and plans to become one of the world’s leaders in uranium production. Famous for its largest Semipalatinsk Nuclear Test Site (SNTS in operation from 1949 to 1989) and a launching site of Soviet and, currently, Russian space programs (including launching of the first astronaut Yu. Gagarin), this land now suffers from a terrible nuclear heritage. It now faces the problem of dealing with hundreds of thousands tons of radioactive waste and assurance of radio-ecological safety at operating facilities.

Kazakhstan is one of the rapidly developing countries in the region and possesses up to 15-20% of the world’s stock of uranium ore [1] and commercially produces almost all chemical elements. The country positions itself as an important uranium producer; it is developing its nuclear science that currently operates 4 research nuclear reactors and other facilities including accelerators, cyclotrons, and modern laboratories. It constructs modern laboratory complex in Gumilev Eurasia National University with the first in Central Asia powerful accelerator of heavy ions; there are plans to construct a new nuclear power plant (NPP) near Almaty. At the same time, the country earns experience with monitoring of the consequences from so-called peaceful nuclear explosions and assures radiation safety at oil extraction, keeps at high level commercial production of uranium; together with IAEA and the USA it runs a decommissioning program of its fast neutron nuclear reactor, BN-350.

Below there is a list of factors that contribute to present radiation situation in the country:

Numerous tests of nuclear weapon and nuclear explosions performed in different places for economic purposes such as “Azgir”, “LIRA” and other facilities; 456 nuclear explosions have been performed at former Semipalatinsk Nuclear Test Site; there are total 5 nuclear test sites in Kazakhstan;

for instance, surface activity of Cesium-137 in the central part of Eastern-Kazakhstan Oblast ranges from 65 to 100 mCi/km2

- global atmospheric radioactive fall-outs due to surface and air nuclear tests in other countries
- high level of natural background radiation, the rate of which, for instance, in Almaty is three times higher than in New York City or Moscow; this pattern is evident in regions rich with uranium and thorium/rare-earth metal ore.
- high content of radio-nuclides in natural waters of "uranium ore provinces"
- activity of uranium mining and uranium production industry and related to uranium production geological explorations
- activity of non-uranium mining and production industry (oil, coal) and accompanying processing enterprises that mine and use raw materials with increased concentrations of natural radio-nuclides
- activity of nuclear facilities – 4 operating nuclear reactors and one NPP at decommissioning since 1999
- other commercial and civil enterprises (industry, science, medicine) that utilize radioactive materials; there are more than 800 enterprises in Kazakhstan that use about 80,000 sources of ionizing radiation with total activity more than 250,000 Curies.
- various radioactive waste; a hundred burying places dispose 225 million tons of low-level radioactive waste with total activity more than 230,000 Curie.

About 13% (350,000 km2) of Kazakhstani territory is subjected to influence of known radiation hazards this area covers territory 19 times exceeding the territory of SNTS. To compare the scale, this area is the size of Germany. Within this area, there are more than 1 million people living with increased exposure to radionuclides.

Presented above are academic facts that illustrate the importance of the radio-ecological problems in the country, but they cannot describe their impact on the social and political life of the country. Within academic consideration one should keep in mind other related facts about Kazakhstan that, to a certain extent, may add to understanding of the complex situation in the country and also the role of international community/organizations in it:

Actual, but not just manifested dedication of Kazakhstan to the principles of open democratic development in the field of non-proliferation, peaceful utilization of nuclear technologies, international cooperation in solving global and regional ecological problems. Those who study political situation in Central Asia describe quite specific from western point of view "face of democracy" in the region. It should be stressed that progress in nuclear-related issues in Kazakhstan is coherent with internationally recognized understanding of activities in this field.

Kazakhstan is the only state in the world's history that, having really possessed nuclear weapon for a very short period of time (1410 nuclear warheads), voluntarily refused possession, keeping at its territory and development of this weapon. (Actually, Ukraine returned Soviet nuclear weapons back to Russia as well, but there was a great deal of paltry bargains.) This fact is one of the few that create the positive international image of our country. It becomes of even greater value when the geopolitical situation in Central Asia is taken into account.

All nuclear related facilities and sites are open to international inspections and assure non-proliferation measures. Kazakhstan is a party to START-1, the Nuclear Non-Proliferation Treaty (NPT), and the Comprehensive Test Ban Treaty (CTBT).

Kazakhstan still keeps its positions in advanced nuclear-related and radio-ecological research; in this field it works in close cooperation with the USA, EU, Japan, Russia, and other countries.

Kazakhstan is one of the leading producers of uranium fuel in the world.

When the USSR collapsed, Kazakhstan was left alone to solve huge radio-ecological problems at its territory as a consequence of terrible Soviet heritage.

Kazakhstan is receiving pioneering experience solving radio-ecological problems during decommissioning of Aktau reactor BN-350.

Overview of factors contributing to radio-ecological situation in Kazakhstan

In investigations of radio-ecological situation and development of measures for lowering radiation risks to people and land subjected to radiation hazards, one should first of all identify radiation sources. All radionuclides are traditionally classified as natural and artificial ones. Opposite to natural radionuclides that normally exist in environment, artificial ones are those, generated as result of human activity in nuclear explosions or in nuclear reactors.

In international practice when environmental impact assessment includes nuclear component1 due to, for instance, activity of uranium mining industry, an accident at a nuclear facility or in a place of radioactive waste disposal, there is, as a rule, the only source of contamination or potential radiation hazard. From this point of view, Kazakhstan becomes a very unique example because in some territories several mutually independent factors are nuclear contributors to the general radiation situation. This situation becomes even more dramatic when one realizes that some of the contributing factors are poorly studied and radiation hazards from other sources have sometimes been underestimated.

A good example is Western Kazakhstan oblast where several radiation hazardous objects of different type contribute simultaneously into the radiation situation in the region. Radiation situation in Aktau city of Mangystau oblast in Western Kazakhstan has been affected by the Mangyshlak Atomic Energy Combine with reactor facilities BN-350, the sites of underground nuclear explosions at Plato Ustiurt, extracting and processing uranium facilities and a large number of operating their oil extracting companies.

Reactor Facilities BN-350

Construction of one of the most powerful breeding reactors in the world BN-350 was started in 1964 in Aktau and in 1973 it was commissioned. For more than 25 years till 1998 it was a reliable source of heat and electricity for the entire Mangyshlak Peninsula:

1) Thermal power – 1000 MW, 2) Electric power – 350 MW, 3) Up to 120,000 tons of desalinated water per day, 4) Buildup of tons of weapon-grade plutonium, 5) Primary loop coolant – liquid sodium, and 6) Fuel enrichment – large amounts.

In April 1999 according to a governmental decree, the Aktau reactor was stopped and a decision was made to transfer it into long-term safe store for 50 years followed by final dismantling. Since that time huge scope of decommissioning works are in progress with financial and technical support provided by the USA and International Atomic Energy Agency (IAEA).

Decommissioning of such facilities has no analogy in the world’s history. Coolant of the primary loop, tons of liquid sodium that is a very active chemical even at room temperature, was kept at temperature 400ºC and during operation became highly radioactive. Decommissioning implied multiple operations with nuclear materials including processing, packing, transportation to thousands kilometers, handling-over manipulations, long-term storage (ageing) in water, conversion of radioactive waste into stable form for final disposal, etc. Nuclear materials in this case are highly enriched nuclear fuel, spent nuclear fuel, radioactive sodium from the primary loop, other various-type radioactive waste. Each step of decommissioning program brings up a challenge to scientists, engineers, specialists from various fields to assure physical protection and nuclear non-proliferation measures (first of all, for plutonium-containing elements), radiation and operational safety, lowest risks for personnel, population and the environment.

Decommissioning of a nuclear reactor is, according to international experience, an extremely expensive project that takes many years of realization. In 2002 decommissioning plan presented by

[1] It should be noted here that everywhere in the world environmental impact assessment is performed as a complex investigation that evaluates relative contributions to environmental conditions from different factors. Such investigations may need expertise of specialists in various fields ranging from chemistry and biology to sociology and environmental law. But when there is a nuclear component among the contributing factors, an entirely different team of specialists is involved and very different organizations became in charge of the investigations. Nuclear-related issues, being sensitive, are always considered in a very different manner.

Kazakhstan passed preliminary expert assessment in IAEA, upon correction this plan is to be presented to independent expertise and, after approval in Kazakhstan, will be presented to country donors for consideration of possibilities for funding.

Naturally, this project intensified through radio-ecological investigations and the monitoring of radiation situation at the site and their adjacent territories. Conclusions made by specialists from the Institute of Nuclear Physics of National Nuclear Center of the Republic of Kazakhstan upon many years of studies say that in all environmental samples taken at territory of sanitary-protection zone and monitoring zone of BN-350 reactor content of artificial radionuclides corresponds to average for Western Kazakhstan levels of global fall-outs. Available retrospective data on releases also evidence that during the whole operation period of the reactor plant there was no exceeding in acceptable annual environmental release of radioactive substances.

Therefore, contribution of BN-350 into radio-ecological situation within the sanitary-protection and monitoring zones can be detected employing highly-sensitive methods and this contribution is vanishingly small and does not result in quality change of the environment. At those territories there were revealed no single case of exceeding regulatory allowable contamination of environment with artificial radionuclides [3].

Underground nuclear explosions

In 1983–1984 in the Northern part of Karachaganak oil and gas field at Plato Ustiurt were performed six so-called peaceful nuclear explosions to construct underground cavities for storage of gas condensate. These cavities known as LIRA facilities are of about 50,000 m3 each and lie 800 – 900 m below the surface. The explosions did not result in release of any significant amount of radioactivity and the cavities, except one of them is filled in with groundwater, were used for gas storage at Soviet times. In 1990s new oil operators in independent Kazakhstan refused utilization of these cavities in their technological process.

Since 1998 INP NNC RK was in charge of scientific investigations and radiation safety assurance at LIRA facilities. As a result it was revealed, that at near-mouth sites of the explosion wells there are local areas of soil contaminated with artificial radionuclides 90Sr and 137Cs. According to walk γ-surveillance, there is insignificant area up to 50 m2 with registered exposition dose rate (EDR) for γ-radiation of about 25-30 μR/h at background values for that region 8-10 μR/h. Since there are no inhabited places in the vicinity and the rate of radioactive contamination is low (within allowable limits), these sites do not impose considerable radiation hazard on the region.

There are still concerns about potential hazard from LIRA facilities. If radionuclides formed at nuclear explosions came out to the surface and distributed uniformly over it, soil at the territory exceeding 500 km2 would be considered as radioactive waste. So, it is necessary to prevent proliferation of radionuclides from the cavities to human environment through wells, technological lines or migration in underground water.

Based on obtained results, specialists made the conclusion that current radio-ecological situation at LIRA facilities is stable and safe. No radiation anomaly of exceeding radiation background was revealed. There has been established a well-developed radio-ecological monitoring system that enables registration of unfavorable trends in radiation situation at the site. Therefore, at present time LIRA facilities are not a source of radioactive contamination and do not impact radiation situation in the region [4].

Natural radionuclides are of much greater concern, since their main sources are tailings from oil extraction, mining and uranium industries.

Oil extraction facilities

In recent years, it has become increasingly evident that the subject of radiological protection of the environment including that of wild plants and animals from radiation exposure, as opposed to the more frequently accepted interpretation in terms of the possible resultant impacts on humans arising from contamination by radionuclides, has an increased profile on the scientific/political agenda.

Currently, radioactive contamination with natural radionuclides at industrial sites of oil-and-gas fields is well known among specialists, but still an unresolved problem in many countries.

Oil and bearing strata contain radionuclides of radioactive series U-238 and Th-232. Upon radioactive decay and leaching processes there is a continuous formation of radium isotopes in oil. Content of radium in water-free oil condensate is at levels of about 280 Bq/m3. In Karachaganak oil-and-gas field specific content of natural radionuclides (226Ra) in extracted condensate lies within the range 0.4 Bq/kg (annual average content) to 3-7 Bq/kg (i.e. up to 510 Bq/m3).

Extraction and transportation of oil condensate is accompanied with carrying out to day surface of considerable amounts of materials with increased content of natural radionuclides. Amounts of radioactive materials accumulated at the fields are described in terms of thousands tons, activity of radionuclides delivered to human environment – in dozens of Curie; and up to 70% of radioactivity is accumulated in pressure-compressor pipes and other metal equipment. Such amounts of radioactive materials increase natural background for orders of magnitude at total areas of several hectares and must be taken into account due to the hazard imposed on personnel and population [5].

Contaminated metal discard, particularly pipelines, is of highest hazard due to their possible unauthorized utilization by local population for water supply and construction. Such metal discard at oil extraction fields is incompletely accounted for, rates of their contamination and related factors of radioactive hazard such as mass amount and activity have not been determined for most cases.

In the region, where oil-extracting companies operate were 231 registered radioactive anomalies [6], 192 of which were classified as man-caused technological radioactive contamination sites. Actual source of radioactive contamination are stratal water in the zone of water-oil interface. Stratal waters at oil fields contain highest concentrations of radium (10-8–10-11 %) compared to all other known stratum waters, except waters from uranium fields.

Anomalous spots with masout soil cover areas of up to tens thousands square meters with EDR of 30 ÷ 100 μR/h at natural background 8-11 μR/h. Such soil is brown and usually covered with solid oil skin. At places of extensive or multiple releases, average level of radioactive contamination comprises for γ-radiation 250-600 μR/h at territories of tens or hundreds of square meters; local maximal readings may be as high as 1000 – 2800 μR/h. Internal surfaces of equipment and tank bottoms keep sediment oil-slime and salts with high radionuclide content. Radioactivity of metal discard comprises on external surfaces 400 – 10,000 μR/h. At all oil extraction sites, mainly at middle- and final stages of exploitation, technological equipment and pipelines are contaminated with natural radionuclides.

Spent uranium mines

In 2002 specialists from INP performed over-all radio-ecological investigation of two spent uranium mines 20 km away from Aktau [6].

Not all the tailings are covered what stipulates their negative impact on environment with direct radiation impact from gamma-radiation, radon emanation and aerosol-dust proliferation, transport of uranium and radium with periodical water flows into soil water horizons and local hydrological system.

Keeping in mind years of dramatic political transformations in the country and years of economical chaos, one should note that along with natural factors contributing to radioactive contamination of environment there is another, equally hazardous influence. This is radioactive contamination due to uncontrolled utilization of mining tailings in local building or road construction that takes place in inhabited localities adjacent to abandoned sites of geological prospecting and spent uranium mines.

The main contaminating factor is radionuclide-containing dust proliferation. The intensity of this process to a certain degree also depends on weather-climate conditions. One can only reliably determine contribution from this factor only when monitored investigation is undertaken.

Tailing Pool “Koshkar-Ata”

Liquid radioactive wastes from Chemical Hydrometallurgical Plant during its operation were discharged into open off-channel reservoir. The tailing pool Koshkar-Ata was made in natural closed hollow and covers 130 square kilometers, 7-8 kilometers from the Caspian Sea coast and 5 km north of the town of Aktay. Amount of accumulated solid waste is about 104.8 mln. tons including about 51.8 mln. tons of radioactive waste (RW) with total activity 41598.5x1010 Bq [7,8]. During operation of this tailing pool in 1964-1992 amount of waste discharge exceeds considerably the evaporative capacity what resulted in continuous increase of water level and area of tailing pool mirror.

Continuous delivery of tailing material from one source caused formation in 1986-1967 of above-water solid sediment in the southern part of the tailing pool, a so-called “beach”.

In 2003 specialists from INP performed pilot monitoring of dusting from radioactive and toxic waste storage Koshkar-Ata [11]. Main dose-forming radionuclides in the waste stored there are 238U, 230Th, 226Ra and 222Rn; concentration of 226Ra changes from background values of 15–20 Bq/kg to 700–800 Bq/kg. There were revealed quite high concentrations of lead isotopes 210Pb and 212Pb.

Man-caused ecological hazard from the tailing pool is stipulated by two main factors: a) air pollution and soil contamination with radionuclides and heavy metals in adjacent to the tailing territories due to wind erosion from naked bottom sediments and, b) contamination of underground water and possible proliferation of hazardous substances in dense saline solutions into the Caspian Sea.

Due to continuous decrease in water phase level of the tailing pool, area of exposed bottom sediments, a source of radioactive and toxic dust, increases. Water mirror covers 42.5 km2 and shore exposed zone is as large as 34.5 km2. A near-surface disposal of RW is located in the mouth part of the tailing pool. Its detailed gamma-surveillance (covered 8,700 m2) revealed very high radiation levels.

Waste accumulated in the tailing pool substantially influences soil and vegetation in adjacent territories. Immediately at the site, its impact on the physical, chemical and biological parameters is maximal; waste completely covers the surface, makes soil more dense, with higher content of water-soluble salts and less microbial mass in it. Within the site, vegetation is completely vanishing. At the tailing pool, total area subjected to such catastrophic change comprises about 70 km2. Chemical and biological parameters of soils at significant distance from the pool have also worsened; this has been accompanied by vegetation degradation.

When estimated possible technologies for the rehabilitation of this exposed shore zone at Koshkar-Ata, the cost factor becomes crucial since cost of any traditional rehabilitation actions in such a vast area (11 km2) rises up to millions of US dollars what is not affordable for Kazakhstan. Traditional technologies are technologies that imply isolation of shallow lands with some available and cheap local material such as, for instance, clay or sand, or those are technologies based on processing of soils in order to increase effective size of soil grains (such as processing with polymers). Specialists also look for other cheaper ways to solve the problem [11].

<u>General considerations on example of Mangystau oblast</u>

Based on comparison of existing radio-ecological hazard sources and taking into account presented above description one can get to the following main conclusions:

radio-ecological problems at BN-350 facilities and sites of nuclear explosions are not of the primary concern and they even attract unreasonably much attention;

main accent is to be done on investigation of the radio-ecological problems in the regions where transport and redistribution of natural radionuclides takes place due to commercial activity;

natural radionuclides that come from uranium and oil-extracting industries are of the highest radiation hazard for population and environment.

Surprisingly, these conclusions made for one of the regions in Kazakhstan may be expanded to other parts of the country. Speaking about nuclear issues in Kazakhstan, we first of all recollect Semipalatinsk Nuclear Test Site (SNTS), but upon thorough consideration and based on authoritative opinion of the scientists involved in radio-ecological investigations there, one can also conclude that to a certain extent the situation is under control. Of course, huge efforts were made recently to make the situation there “near-stable”.

<u>Semipalatinsk Nuclear Test Site (SNTS)</u>

According to official data, from 1949 to 1989 there were performed 456 nuclear tests with total 607 nuclear charges involved; among that there were performed 116 atmospheric nuclear tests (80 tests in air and 6 at high altitude), 30 surface and 340 underground tests including 4 underground excavational (with rock outbursts).

During recent years many research groups and scientific institutes studied character and scale of contamination at the test site. Scope of investigations is impressive while there are still minor parts of the test site that has never been thoroughly investigated because of huge territories it covers. Lots of information is available resulted from performed and on-going research [13-24, 30]. According to character and contamination scale, sites of the polygon may be grouped into three characteristic types:

areas with area contamination as a result of surface and atmospheric nuclear explosions

sites contaminated by excavational and contingency underground explosions

near-mouth sites of the wells with water effects.

Most concern there now is paid to the mountain range Degelen where 209 explosions were performed. Radioecological situation there is not stable and tends to worsening. Currently conservation (sealing) of pits where water flew out from is finished what to certain extend stopped further contamination of surface lands, but does not completely eliminate the hazard.

In places of excavational explosions and unexpected surface releases there are local spots of contamination with high concentrations of transuranium elements 239+240Pu and 241Am and activation products 60Co, 152Eu, 154Eu, etc. Contamination there is mainly concentrated in cones formed due to explosions or close to them. As a rule, most of radionuclides is associated with large-grain soil fractions and is strongly chemically bound there. Therefore, the radio-ecological situation there is stable and all what is required to do is to prevent access to those places. Remediation measures there would be needed if the lands are needed for commercial or agricultural activity.

Ground and air tests resulted in contamination of considerable territories, but its average rate is not high approaching, for most of the territories, several thousands Bq/kg. There are no primary contaminators with several same-rate concentrations of decay products such as 90Sr and 137Cs or residual plutonium isotopes. Specialists consider some administrative restrictions for types of commercial activities at these territories enough.

Considerable time has passed since the polygon was closed. By now activity of strontium-90 and cesium-137 has decreased twofold, but the alpha-activity of plutonium remains almost the same.

There is growth of commercial activities at the site with active exploration of mineral resources at Karazhara and Zhaksytyz Lake, geological prospecting and some agricultural activities.

Radio-ecological situation in Kazakhstan – main conclusion

Radio-ecological investigations performed within various State programs since 1992 [12] have confirmed that a priori concerns about extremely unfavorable radio-ecological situation in the Republic of Kazakhstan. Not all the territory of the republic was subjected to comprehensive radio-ecological investigations. At investigated territories were revealed contaminations with radionuclides of different environment components with contamination spot sizes ranging from hundreds square meters to several thousand square kilometers. Annual effective dose at those areas varies from the values that require establishing continuous monitoring over environment and sites to the values that require removal of local population from contaminated territories in accordance with Radiation Safety Norms NRB-99 [32].

Public concerns

In the beginning of 2004 we made a brief survey trying to determine the extent of international public attention to nuclear-related issues compared to other events in our country. In analytical papers published during last 4 years (2000-2004) in electronic journal Analyst by Central Asia-Caucasus Institute of the Johns Hopkins University Kazakhstan was mentioned 210 times; in those papers radio-ecological issues were mentioned 4 times and only 2 papers were somehow devoted to these issues:

“Kazakhstan’s Semipalatinsk Relief and Rehabilitation Program”

“KazAtomProm is Lobbying for Importing Nuclear Waste”

Nuclear-related public concerns within the country are of much greater scale. A good indicator might be recent discussions on the import and disposal in the region of Kazakhstan of intermediate- and low-level radioactive waste.

The idea was to import foreign low-level waste to cover expenses for disposal of our own radioactive waste. Assessments show that amount of radioactive waste in Kazakhstan is hundreds of thousands tons and money required to dispose it properly, as reported to the Kazakhstani Parliament, exceeded $1,110,000,000 USD; such tremendous expenses are absolutely unaffordable for Kazakhstan. A large portion of this waste was generated during Soviet times and after the USSR collapse, Kazakhstan was left alone to solve the waste problem. According to current Kazakhstani legislation, import of nuclear waste is prohibited. Recently, public discussions were very active.

For instance, a popular talk-show at State TV channel "Khabar" gained interesting statistics. During TV-debates there was a tally of telephone calls from people who support or refuse the idea of waste imports. The total number of calls was 482; 239 of them voted "FOR" and 243 were "AGAINST" the idea. As well, for our city ~500 calls for 40 minutes is a very big number, for example another episode of this show discussed issues of corruption in upper-level authorities collected only about 200 calls [29].

Discussion of these issues was not hindered and by now is the only example in Kazakhstan when the authorities did not interfere with public discussions and followed the public will.

Radiation Exposure – general case

Entire nature of radiation makes "zero exposure" impossible. Nuclear science and technology when refer to safety assurance widely operate with the principle ALARA – "as low as reasonably achievable" which implies decrease of exposure levels from artificial sources to the lowest possible levels. At the same time radiation is an inalienable part of our existence. According to IAEA data, average doses gained by people on the Earth are accumulated due to the following factors: 72.999% is exposure from natural radiation, 20% - from medical diagnostics, 7% due to influence from nuclear explosions performed worldwide and 0.001% of the total dose gained by a person is due to activity of nuclear power plants.

For instance, transcontinental flight at altitude 9,000 m results is a dose accumulation comparable with x-ray examination. This dose is gained at high altitude where Earth's atmosphere and, depending on geographical latitude, magnetic field have much lower protective action against cosmic radiation.

Doses gained from natural background radiation depend on geographical location of a place – content of radioactive isotopes in the earth's crust and rock formations – and geographical latitude that defines cut-off rigidity for cosmic rays that reach earth's surface.

Radioactive Fallouts

Another contributor to continuous irradiation is radioactive fallouts distributed as spots over earth's surface:

At explosion of nuclear weapons in close to the earth's surface, the detonation pulverizes surface material and sucks much of it into the hot mass that rises as a mushroom cloud. Inside the fireball and stem of the bomb cloud the radioactive particles become attached to heavier particles. Depending on the size/mass of formed bits of matter they fall back to earth within minutes, hours and much longer periods of time, forming different type fallout. Microscopic particles sweep around the world in a zone at the latitude of the explosion and are brought to earth with precipitations. If the detonation injects the bomb debris into the higher stratosphere, we refer to stratospheric, or global, fallout. Particles there may remain aloft for long periods of time and are scattered horizontally, spreading throughout the stratosphere.

During a nuclear explosion up to approximately 300 different radioactive isotopes are formed. Since many of them are extremely short-lived, the total radioactivity from the bomb decreases more than a hundredfold within the first hour after the explosion. But remaining long-living isotopes constitute the long-term radiation hazard primarily through contamination of the foods that are consumed by humans or inhalation with dust. From chemical point of view, radioactive isotopes are "indistinguishable"; radioactive strontium or potassium, for instance, are deposited in human bone and lead to a higher incidence of leukemia and bone cancer, and 131I (half-life of only eight days) becomes concentrated in the thyroid gland, where it causes thyroid cancer.

Conclusion

Beyond a description of current situation with radio-ecological issues in Kazakhstan we would like to make an inevitable statement that people in a modern world have to find ways to survive and live in conditions of increased radiation background and further development of nuclear technologies.

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================================ **ДОКЛАДЫ** ================================

ГЛАВНЫЕ ФАКТОРЫ ВЫБРОСОВ CO_2 В АТМОСФЕРУ В ЦЕНТРАЛЬНОЙ АЗИИ: АНАЛИЗ ЗАГРЯЗНЕНИЯ ВОЗДУХА ОТ СГОРАНИЯ ТОПЛИВА

© 2005 г. Е. Каракая, М. Озчаг

Отдел экономики Университета Аднан-Мендерез,
09800 Назили / Айдин, Турция

Глобальное потепление ставит серьезные угрозы для окружающей среды, экологии и социально-экономической системы. К примеру, в аридных условиях Центральной Азии, Аральское море было подвергнуто антропогенному влиянию невиданных масштабов Концентрация выбросов CO_2 в атмосфере повышается, как результат многообразия человеческой деятельности, где ведущая роль принадлежит сгоранию горючих ископаемых.

С начала 1990-х годов изучение глобального потепления приняло международный характер и приобрело мировое значение. План эффективной и приемлемой политики по контролю изменения климата, требует понимания правил зависящих от различных факторов производства CO_2. Данное исследование ставит своей задачей анализ изменения источников выбросов CO_2 в пяти странах Центральной Азии в период 1992-2001 гг. Для этой цели мы используем технику разложения, которая изучает влияние изменений происходящих в численности населения, на интенсивность энергетической выработки, экономический рост; предварительная обработка с последующим использованием энергии и интенсивности выделения водорода вместе с выбросами горючих ископаемых. Данные показывают, что начиная с 1992 года выбросы CO_2 уменьшились в Таджикистане, Казахстане, Киргизстане. Нами установлено, что главная причина уменьшения выбросов CO_2 связаны с экономическим сокращением производства после распада Советского Союза. Другие факторы внесшие вклад в этот процесс – улучшение в энерго интенсивности и упадок в энергодеятельности. Хотя Туркменистан и Узбекистан так же испытали подобный экономический спад, в тот же период, выбросы CO_2 здесь увеличились. Это объясняется использованием их энергии в структуре энергорынков. Энергоинтенсивность очень сильно увеличилась в этих странах, что объясняется либерализацией энерго секторов, увеличивающих энерго интенсивность. Можно предположить, что с либерализацией, Туркменистан и Узбекистан найдут возможности улучшить эффект энерго-интенсивности и наоборот уменьшить уровень выбросов CO_2. В целом, исследование показало, что Центрально Азиатские страны начиная с 2000 года находятся в стадии выздоровления. Поэтому существует вероятность, что выбросы CO_2 начнут увеличиваться в будущем хотя энерго-интенсивность и содержание углерода в энергии могут уменьшиться благодаря изменениям в проводимой политики и адаптации производства.

DRIVING FORCES OF $C0^2$ EMISSIONS IN CENTRAL ASIA: A DECOMPOSITION ANALYSIS OF AIR POLLUTION FROM FOSSIL FUEL COMBUSTION

© 2005. Etem KARAKAYA and Mustafa ÖZCAĞ

Department of Economics,
Adnan Menderes University,
Nazilli / Aydın, 09800, TURKEY

Introduction

Global warming poses serious threats on environment, ecology and socio-economic systems. In the arid ecosystem of Central Asia, for instance, the Aral Sea has been subjected to an unprecedented degree of negative anthropogenic impacts. In this region, agricultural production has already decreased in some commodity groups and quantities and qualities of water resources are at particular risk of severe effects of climate change. There is widespread scientific agreement that increases in greenhouse gases

(GHG) contribute to the problem of global warming. This serious global climate change problem has resulted in proposals to set specific targets for reducing greenhouse gas emissions. The Framework Convention on Climate Change was signed at the World Summit held on June 1992 in Rio-de-Janeiro by more than 150 countries to promote international cooperation for achieving such reductions. The Kyoto Protocol, signed in 1997 at the third meeting of the Conference of Parties (COP-3), goes further and commits developed countries (Annex I) to reducing their greenhouse gas emissions according to individual quantified emission limitation or reduction commitment percentages, and outlines various mechanisms for achieving this goal. Even though, no specific targets were prescribed for developing countries, the Kyoto Protocol demanded that all developing countries should be included in GHG emission reduction efforts (Dessai and Schipper, 2003) . The reductions concern six groups of greenhouse gases: carbon dioxide (CO_2), methane (CH4), nitrous oxide (N2O) and three categories of fluorinated gases (HFCs, PFCs and SF6). The emission of CO_2 is the most important issue, because it has the largest share among the greenhouse gases and while the emission of the other greenhouse gases is decreasing the emission of CO_2 is increasing. The major source of anthropogenic CO_2 emissions is the combustion of fossil fuels (i.e. coal, oil and natural gas). Therefore, in this study, the main attention is given to CO_2 emissions that are resulted from fossil fuel combustions.

Central Asian countries are non-Annex countries and their commitments are to carry out a GHG emissions inventory periodically, as well as vulnerability and mitigation studies. However, any CO_2 reductions by a developing country would contribute to the ease of the global warming issue especially when we consider that mitigation of climate change issue should be a joint international effort. Morover, the Kyoto Protocol has opened new opportunities for participating in GHG mitigation projects through the flexible mechanisms like Clean Development Mechanism (CDM), Joint Implementation (JI) and Emission Trading (ET).

The design of effective and comprehensive policies to control climate change requires an understanding of the rules played by the different factors affecting CO_2 production. By using a decomposition technique, we will try to analyze the sources of changes in energy-related CO_2 emissions for five Central Asian countries for 1992-2001 periods. Decomposition analyses uses historical data to explain which factors contributed how much to the total change in CO_2 emissions (Hamilton and Turton, 2002). Adequate information regarding the sources of these emissions will contribute to the effectiveness of policies to reduce them.

The structure of this paper is as follows. Section 2 analyses main drivers of CO_2 emission changes. Section 3 describes the decomposition method used to compute the effects of several factors on the emission of CO_2 for five Central Asian countries, namely Tajikistan, Kazakhstan, Kyrgyzstan, Turkmenistan and Uzbekistan. The results of the analyses are discussed in Section 4. Section 5 concludes by commenting on how these historical trends and drivers can be used in the development of greenhouse gas emissions scenarios.

Drivers of $C0_2$ Emission Changes

There are few aspects of environmental change that are universally agreed upon. This is due in part to the complexity of the factors that drive environmental change. Evidence continues to accumulate suggesting that much of the change in atmospheric gas concentrations is human-induced. Because human societies enjoy and utilize the environment for the fulfillment of their basic needs (food, clothing, shelter, etc.) and wants (luxury items, social prestige based e.g. on economic status etc.), humans have a vested interest in a healthy and productive environment (Shi, 2003).

Human induced contributions to CO_2 emissions stem mainly from fossil fuel use through energy consumption and industrial production and these emissions have been increasing dramatically since the beginning of the Industrial Revolution. Land-use / Land-cover changes, such as deforestation, also affect the exchange of carbon dioxide between the Earth and the atmosphere (IPCC, 2001).

Human induced emissions are the result of a large set of interrelated driving variables in the domains of demographics, economics, resources and technology as well as environmental policies. In order to analyze human induced driving forces of environmental change, studies take the approaches of either Ehrlich’s IPAT framework or its extended version of so-called Kaya Identity (1990).

The theoretical framework proposed by Ehrlich and Holdren (1974) formulates the drivers of the environmental changes as;

$$I = P \ x \ A \ x \ T \tag{2.1}$$

Which hypothesizes that environmental impact (I) is determined by the interacting effects of population size (P), per capita consumption levels (A, for affluence), and finally the per capita pollution generated by the technology (T) used to satisfy the consumption levels.

Studies of energy-related carbon emissions are structured by using the Kaya identity outlined by;

$$CO_2 Emissions = Population \times \frac{GDP}{Person} \times \frac{Energy}{GDP} \times \frac{CO_2}{Energy} \tag{2.2}$$

Where CO_2 emissions are a function of population, income (GDP per capita), energy intensity (units of energy/GDP), and carbon intensity (CO_2 emissions per unit of energy).

Both formulas suggest that population size, economic growth and technology (in other words, energy and CO_2 intensities) are important in the emission of greenhouse gases. Therefore, in order to understand their influence on CO_2 emissions, it requires a closer look at each of these main driving factors.

The Contribution of Population Growth to Environmental Change

Population size and its growth has been one of the main factors in causing CO_2 emissions because the two seem to go hand-in-hand. If we hold affluence and technology constant, the economic activity required to support an additional person means more resources must be extracted and more emissions are generated. The contribution of population growth on environmental problems is specified through two mechanisms; First, a larger population could result in increased demand for energy for power, industry, and transportation, hence the increasing fossil fuel emissions. Second, population growth could contribute to greenhouse gas emissions through its effect on deforestation. An increase in population causes greater deforestation, land use changes and more consumption of wood for fuel; thus, larger population raises CO_2 emissions and contributes to the greenhouse effect (Birdsall, 1992). Shi (2003) argued that one percent of population growth is associated with a 1.28 percentage increase in emissions on average. The impact of population pressure on emissions has been more pronounced in developing countries than developed countries. However, it should be noted that as population growth slows down on average, its contribution to increases in CO2 emissions declines, meaning that rising CO_2 emissions will increasingly stem from other factors.

The Contribution of Affluence to Environmental Change

Affluence denotes the per-capita level of goods and services produced in a country in a given time period, measured by gross national product (GNP) or gross domestic product (GDP) per capita. Affluence is a critical determinant of environmental degradation because high rates of economic activity are associated with rapid rates of resource use and waste production. In general, increasing affluence tends to exacerbate environmental impacts. Many analyses show that economic growth is responsible for most of the changes in CO_2 emission (see, *e.g.*, Albrecht J. et al, 2002, Luukkanen J. and Kaivo-oja, J. 2002., Ansuategi and Escapa, 2002). Regarding decreasing affluence, the main issue is that there would be no single country that accepts reducing their economic growth.

The Contribution of Technology to Environmental Change

Population and affluence determine the level of economic activity, i.e. the quantity of goods and services produced. Technology is the recipe that defines the combination of capital, labor, energy, materials, and information that are used to produce a good or service. For most goods and services, different combinations are possible. The technology term actually incorporates not only technology as it is usually conceived but also social organization, institutions, culture, and all other factors affecting human impact on the environment other than population and affluence (Nanduri, 1998). There are two ways in which technological change can lower environmental impact. First, it can reduce the materials and energy used per unit of output, which is termed as energy intensity, and, second, it can substitute less harmful technology, which is termed as energy (fuel) switch (Roca and Alcántara, 2001). In the latter case, the fuel switch can take place either from high polluting fossil fuel (eg. Coal) to less polluting fossil fuel (eg. Natural gas) or from fossil fuel to non-fossil fuel.

All three of the factors influencing environmental impact and change are interrelated and future emissions will depend on the complex interactions among population growth, economic growth, and technological innovation.

Decomposition Method

From a policy design perspective, it is important to find out the magnitudes, interrelationships, and significance of the primary human drivers of change in CO_2 emissions. Such information is helpful for the development of energy use and carbon emissions scenarios because it provides modelers with a historical basis from which to extrapolate trends as well as information on how various factors such as population, affluence, energy intensity, and structural trends affect energy use and associated greenhouse gas emissions. In most cases, when we look at environmental changes it is not immediately obvious which force or interplay of forces caused the changes. The questions asked above can be answered by a decomposition analysis, which shows how much changes in certain factors contributed to changes in a specific variable. Decomposition analyses are widely used in energy studies. As a response to climate change policy needs, decomposition analysis has been extended in order to identify the factors influencing changes in greenhouse gases emissions and in particular in carbon dioxide emissions. Ang and Zhang (2000) provides an extensive literature review.

In this study, we present historical energy use and carbon emission trends and try to find out the main driving factors affecting CO_2 emissions changes for the five Central Asian Countries, namely Kazakhstan, Kyrgyzstan, Tajikistan,Turkmenistan and Uzbekistan. Our discussion of the drivers is guided by the terms of the so-called Kaya identity (Kaya, 1990) as outlined by equation 2.2. We have redefined the terms slightly to closely match the available data and the characteristics of the countries concerned that we focus on in this paper. Thus, following Hamilton and Turton (2002), energy related emissions of CO_2 for a given year can be decomposed as;

$$CO_2 = \frac{CO_2}{FOSS}\,\frac{FOSS}{TPES}\,\frac{TPES}{TFC}\,\frac{TFC}{GDP}\,\frac{GDP}{POP}\,\mathrm{POP} \qquad (3.1)$$

The formula links energy-related carbon emissions (CO_2) to fossil fuel consumption (FOSS), total primary energy supply (TPES), total final energy consumption (TFC), level of economic activity, that is gross domestic production (GDP), and population (POP).

Accordingly, the first factor on the right of the formula 3.1, CO_2 /FOSS, measures the *carbon intensity effect*, which is the CO_2 intensity of fossil fuel combustion and mainly reflects the fuel mix. The second factor, FOSS/TPES is the *fossil fuel intensity effect*, which indicates the proportion of total energy obtained from fossil sources. The third term in equation 3.1, TPES/TFC is the *conversion efficiency effect* and it represents the amount of primary energy required to deliver energy for final consumption and reflects both conversion efficiency and fuel mix. The fourth term TFC/GDP is the *energy intensity effect* of economic activity, reflecting both efficiency of energy use and economic structure. These four factors can be considered to represent technological impacts of so called IPAT model. GDP/POP repsents *growth effect* and is a measure of economic output per capita. Finally, POP is the *population effect* and it measures the influence of population growth alone. The latter two factors correspond to the affluence and population in the IPAT model.

At any moment in time, for a country or group of countries, the level of CO_2 emissions due to fossil fuel combustions can be seen as the product of the six Kaya Identity components as outlined above. For small to moderate changes in the Kaya components between any two years, the sum of the percent changes in each of the variables closely approximates the percent change in carbon emissions between those two years (Hamilton and Turton, 2002). Therefore, in order to analyse the historical trends, our decomposition index formula should take the form as follows;

$$\frac{CO_2(_{t=1})}{CO_2(_{t=0})} = \frac{\frac{CO_2}{FOSS}(_{t=1})}{\frac{CO_2}{FOSS}(_{t=0})} \frac{\frac{FOSS}{TPES}(_{t=1})}{\frac{FOSS}{TPES}(_{t=0})} \frac{\frac{TPES}{TFC}(_{t=1})}{\frac{TPES}{TFC}(_{t=0})} \frac{\frac{TFC}{GDP}(_{t=1})}{\frac{TFC}{GDP}(_{t=0})} \frac{\frac{GDP}{POP}(_{t=1})}{\frac{GDP}{POP}(_{t=0})} \frac{POP(_{t=1})}{POP(_{t=0})} \quad (3.2)$$

Accordingly, we can calculate percentage changes of both on the left- hand side (CO_2 emissions) and right-hand side (determinants of CO_2 emission changes) parameters of equation 3.2, and the effects of these factors on CO_2 emissions can be analysed.

Data And Results

This section presents results of our case study of five Central Asian Countries to better understand the relationships between some specific driving factors and total CO_2 emission changes, based on the data and analytical method developed in the previous section. First, we provide a detailed descriptive analysis of the data, then present results of the decomposition analysis of CO_2 changes.

A historical analysis for the period 1992-2001 is complemented. To obtain the data related to the variables analyzed, we have mainly used the databases of the International Energy Agency. CO_2 emissions data that are resulted from fossil fuel combustions for five Central Asian countries are obtained from "CO_2 Emissions From Fuel Combustion for Non-OECD Countries" (IEA, 2003a). Total primary energy supply data for the same countries are obtained from "Energy Balances of Non-OECD Countries" (IEA, 2003b). The data includes all fossil fuels as well non-fossil fuels. Since IEA (2003b) data gives coal, petroleum and natural gas values as seperately, for our fossil fuel (FOSS) paramater, we have aggregated these values by adding them together. For the 1992-2001 periods, data for GDP, Total Final Energy Consumption (TFC) and population (POP) were easily obtained from IEA (2003c).

Table 1: CO_2 Changes and Driving Factors of CO_2 Changes for the Central Asia and five individual countries (*% changes*)

COUNTRIES	CO_2 / CO_2	CO_2 /FOSS	FOSS/TPES	TPES/TFC	TFC/GDP	GDP/POP	POP/POP
Central Asia	-34,94	14,56	-25,73	13,04	-23,34	-17,10	9,52
Kazakhstan	-53,06	14,91	-19,27	20,22	-54,71	0,79	-8,02
Kyrgyzstan	-71,49	62,50	-60,08	26,45	-11,74	-64,07	10,22
Tajikistan	-77,60	9,19	-38,66	6,97	-65,39	-19,05	11,61
Turkmenistan	21,81	2,83	-12,43	13,40	-9,77	-2,49	36,00
Uzbekistan	2,81	-15,06	7,52	-3,43	61,54	-38,44	17,15

Table 1 presents percentege changes in CO_2 emissions and its main driving factors for Central Asia as a region and for five individual Central Asian countries for the 1992-2001 period. As can be seen from Table 1, overall carbondioxide emissions in Central Aisa have declined 34.94% from 1992 to 2001. While World CO_2 emissions showed an increase in average during the same period, such decline in emissions in Central Asia is quite important for the climate change issue. As we look in detail for the individual countries, one can see that while Tajikistan, Kyrgyzstan and Kazakhstan reduced their CO_2 emissions quite substantially, emissions in Turkmenistan and Uzbekistan increased during the same period. In order to better understand what the main driving factors of these CO_2 changes are during this period, it is essential to take a closer look at each effect in detail. In this section, after analysing the results for the whole region, a detailed analysis will be carried out for the effects of the main factors that caused CO_2 changes for individual countries.

Even though Central Asian countries as a whole have made significant contribution to reducing CO_2 emissions, it is important to note that none of these reductions have resulted from conscious domestic climate mitigation policies. When analysing the 34.94% decline in CO_2 changes in Central Asia, it is evident that this decline was achieved mainly due to a substantial economic contraction that was experienced during the 1992-2001 period. After gaining their independence, such economic decline was a common characteristics of the majority of former Soviet Union countries (Pomfret, 2003).

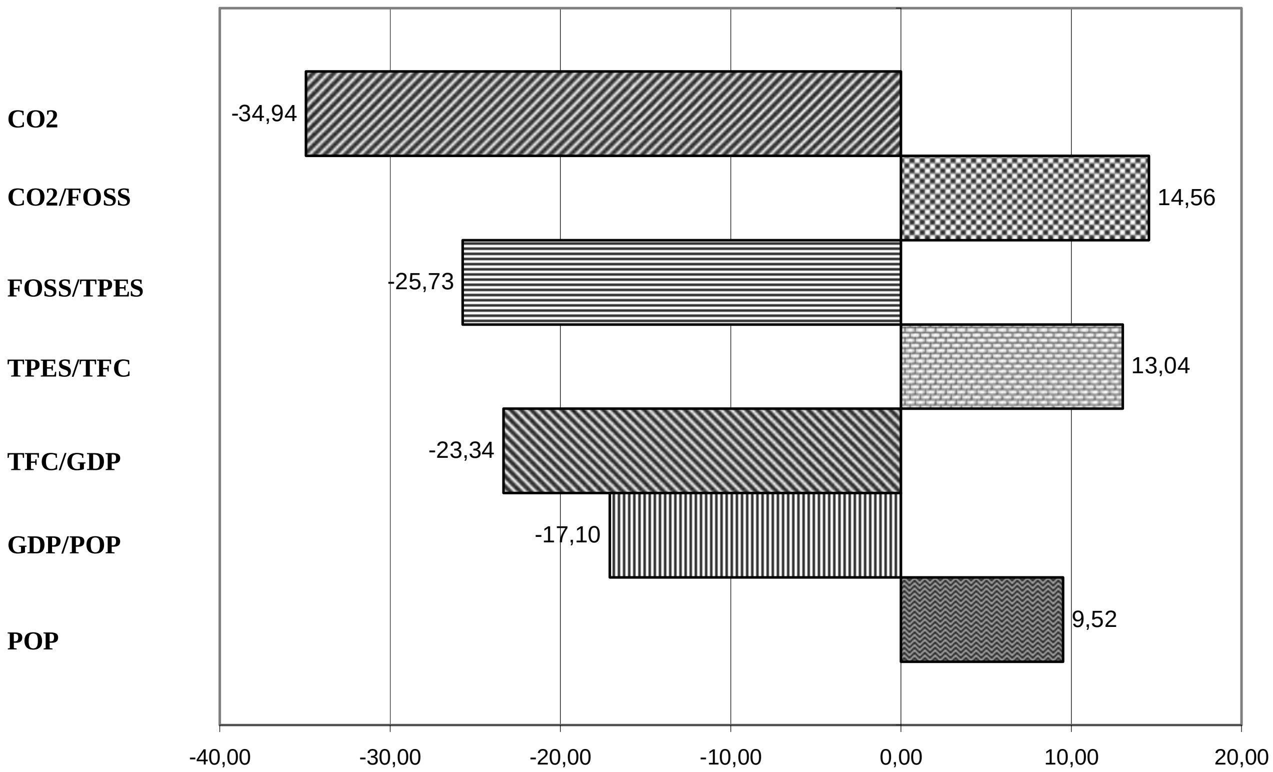

Fig. 1. 1992-2001 Average of Central Asia

Equally important, a decrease in overall energy intensites have contributed to such decline in CO_2 emissions for the region. Fossil fuel intensity effect, which implies fuel switch towards less carbon emissions, also contributed to reductions in CO_2 emissions. On the other hand, carbon intensity effect, Conversion Efficiency Effect and population effect were positive during this period and offset such reduction to some extend.

As mentioned earlier, CO_2 emissions were reduced quite substantially in Tajikistan, Kyrgyzstan and Kazakhstan since 1992. Our results suggest that main decreases in CO_2 emissions in these countries are mainly due to a serious economic contraction after the collapse of Soviet Union. Negative growth effects in Tajikistan and Kyrgyzstan are %65 and %64 respectively. The growth effect in Kazakhstan barely reached positive values, which is %0.79, in 2001, yet during the previous years the GDP growth has always been negative. Even though, the other two Central Asian countries, Turkmenistan and Uzbekistan, also experienced similar economic contraction for the same period, their CO_2 emissions have increased.

This could be explained by their energy use patterns and energy market structures. Energy intensities, which is measured by the amount of total energy per unit of GDP, have increased significantly for these countries. Energy intensities are extremely important not only for CO_2 mitigation policies but also for sustained economic growth. If one manages to improve its energy intensities, it means that less energy is used in order to produce the same amount of output, which in turn leads to lower costs and emissions. This argument is supported by our findings. Even though Kazakhstan did not experience big economic decline compared to Uzbekistan (growth effects in Kazakhstan and Uzbekistan are +0.79% and -36.44% respectively), CO_2 emissions in Kazakhstan declined over 53% while Uzbekistan's CO_2 emissons increased over 2% during the 1992-2001 period (See Table 1). This contradictory outcome indicates the importance of energy intensities. As can be seen from Table 1, changes in energy intensities for Kazakhstan and Uzbekistan show different patterns. While Kazakhstan improved its energy intensity by reducing it upto 54.75%, energy requirement per unit of output in

Uzbekistan increased by 61.54% in 2001 compared to 1992. Therefore,ceteris paribus, it can be argued that the reason behind Uzbekistan's CO_2 emission increase is due to inefficient energy use during this period. In our earlier study, which analysed the determinants of CO_2 changes in Central Asia for the 1992-1999 period, a substantial deteriotion in energy intensities were estimated in the case of Turkmenistan, which showed a 47% increase in energy intensity effect (Karakaya and Özçağ, 2004). In this updated study, however, it is estimated that energy intensity effect in Turkmenisten has improved significantly between 1992-2001 period. This dramatic change in energy intensities within two years could be explained by extra-ordinary economic growth that was experienced by Turkmenistan, which was reported as 17% in 2000 and 20.5 percent in 2001 Rapid economic growth was due to massive increase in natural gas production,where its amount was more than tripled between 1998 and 2001, and mainly this production was exported(Pomfret, 2003).. On the other hand, total final energy consumption, TFC, remained almost the same during the same period. Therefore, an increase in real GDP and stable TFC made energy intensity effect, defined as the ratio of TFC to GDP, look improved within two years.

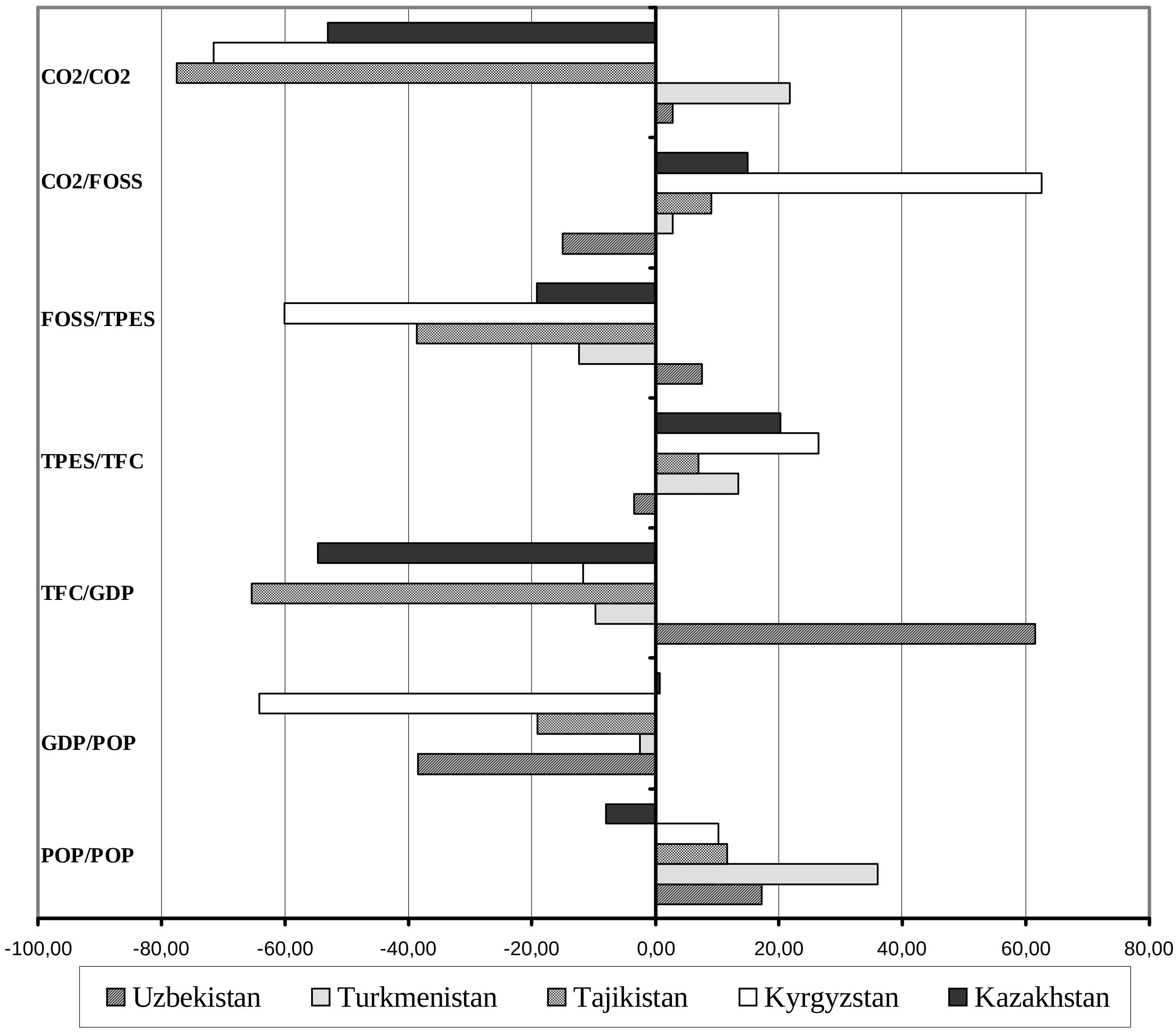

Fig. 2. CO_2 Emissions and CO_2 Determinants of Central Asia in 1992-2001

Regarding CO_2 intensity effect, it can be seen that all countries have experienced increases in CO_2 intensities with the exception of Uzbekistan. The positive CO_2 intensity values should be interpreted cautiously. We believe that such results indicate that there was no major energy switch among the fossil fuels (e.g. from coal to natural gas). Since energy production declined quite substantially during this period, it might be considered that such fuel switch was not needed. As our findings suggest, major fuel switch from coal to natural gas was observed only in Uzbekistan. With regard to fossil fuel intensity effect, we see that, except Uzbekistan, all countries improved their situation, which suggests that some degree of fuel switch took place between fossil fuel to non-fossil fuels. Fossil fuel intensity effects were especially stronger in the case of Kyrgyzstan and Tajikistan, where fuel switch were towards hydro-electric energy sources as abundant water resources give them significant hydroelectric potential (MEEKR, 2003; MNP, 2002).

Finally, we can see that population effect has contributed to increase in CO_2 emissions in the Central Asian Countries with the exception of Kazakhstan. Negative population effect in Kazakhstan is due to emigration of some non-Kazak citizens to Russia and Europe after the collapse of Soviet Union (UNDP, 2002). Population effect is especially stronger for Turkmensitan and can be considered as one of the main contributor to increase CO_2 emissions as the population increase reached over %36 during the 1992-2001 period.

Conclusion

The analysis of the trend of CO_2 emission changes is a useful reference point for designing energy and enviromental policies in a nation. The decomposition analysis presented in this study leads to some interesting conclusions about the factors that have influenced changes in CO_2 emissions from the Central Asian countries for the 1992-2001 period. Our main findings can be listed as follows;

- Population effect is mainly stable in Central Asian countries.

- The above results make clear that the observed reduction of overall CO_2 emissions in Central Asia is practically owed to the crisis that has experienced by these countries after gaining their independence from the Soviet Union.

- Fuel switch among fossil fuels took place mainly in Uzbekistan. Fuel switch from fossil fuels to non-fossil fuels took place in all countries except Uzbekistan.

- Energy intensities are key elements of energy-saving and carbon-reduction plans. While Tajikistan, Kazakhstan, Kyrgyzstan and Turkmenistan (only recently) improved their energy intensities, Uzbekistan has problems in reducing their energy efficiencies.

The study stresses that most of the Central Asian countries have been experiencing a recovery since the beginning of 2000. Therefore, it is possible that CO_2 emissions will begin to increase in the future unless energy intensities and carbon content of energy are improved via policy changes and/or behavioral adaptation. Some Central Asian countries improved their energy intensities, yet there is still great potential to improve their energy saving positions. It is suggested that liberalization of energy sectors improves energy intensities (Cornillie and Fankhauser, 2002). Therefore, it can be argued that, with liberalization, especially Uzbekistan and Turkmenistan can find possibilities to improve energy intensity effects and in return reduce CO_2 emission levels.

Another important mitigation policy in the case of Central Asian countries could be switching energy from coal and petroleoum fuels to renevables or at least to natural gas as they have aboundant resources in the latter case.

Finally, flexible mechanisms (Clean Development Mechanism, Joint Implementation and Emission Trading) introduced by the Kyoto Protocol can offer great opportunities for the Central Asian countries in order to find financial support for their climate change mitigation policies. While CDM and JI projects can be applied to all Central Asian countries, Emission trading could be a main financial resource especially for Kazakhistan as tradeble amount of emission reductions that has been gained since 1992 in Kazakhstan totals to a substantial amount.

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================================ **ДОКЛАДЫ** ==================================

ДИНАМИКА РАСТИТЕЛЬНОГО ПОКРОВА В АРИДНЫХ ЗЕМЛЯХ ЗАПАДНОГО КИТАЯ С 1982 ПО 2000

© 2005 г. Куингдонг Ши[1], Джиагво Ки[1,2], Ксиаолинг Пэн[1], Гуангуи Льви[1], Кингсан Ши[1], Хейян Лу[1]

[1] Лаборатория экологии Оазиса Ксинжианг Ки,
Международный центр Устойчивого развития в аридных и семиаридных землях,
Урумки, Ксинжианг, Китай
[2]Центр исследований глобальных изменений климата и земли, Географический отдел, Мичиганский Государственный Университет,
Ист Лензинг, Мичиган, США

Доминирующее влияние на состояние и динамику растительного покрова в рассматриваемых регионах оказывают антропогенные факторы. Изменение растительного покрова в аридных регионах западного Китая было проанализировано в период от 1982 до 2000 гг. Данные о фракционном составе растительного покрова (ФРП) были получены NOAA/AVHRR в разное время, методом воздушного деления, (Shi, 2003), который был использован для анализа изменений в фракциональном покрове в данный период. Были установлены движущие факторы изменения растительности в аридных территориях Западного Китая, путем анализа температурных изменений для каждого типа растительных сообществ в различных регионах. Таким путем были установлены характерные различия растительности в Аридных территориях Западного Китая. Было выявлено, что между различными регионами в пределах Западного Китая существуют характерные различия. В Северном Ксинжианге общая территория опустынивания уменьшилась, в то время, как площадь лесов увеличилась за последние два десятилетия, результатом чего стало улучшение растительного покрова прилегающих территорий. Однако на высоких равнинах Квайдам, общая территория пустыни увеличилась на границе исчезающих лугов, что в результате привело к уменьшению продуктивности всего растительного покрова.

На равнине, общая территория пустыни не изменилась, в то время как оазис продолжает расширяться через Ксинжианг, в результате чего сокращаются экотоны перехода к средней и высокой продуктивности травяного покрова. Выяснилось, что человеческая деятельность является одним из важнейших факторов, влияющих на изменение типа растительности в аридных территориях Ксинжианга, хотя ученые говорят об изменении регионального климата в этой части Китая.

VEGETATION COVER DYNAMICS IN THE ARID LANDS OF WESTERN CHINA FROM 1982 TO 2000

© 2005. Qingdong Shi[1], Jiaguo Qi[1,2], Xiaoling Pan[1], Guanghui Lv[1], Qingsan Shi[1], Haiyan Lu[1]

[1]Xinjiang Key Laboratory of Oasis Ecology; International Center for Sustainable Development in Arid and Semi-arid Land, Urumqi, Xinjiang, China
[2]Center for Global Change and Earth Observations; Dept. of Geography, Michigan State University, East Lansing, Michigan, USA

Introduction

The amount of data and remote sensing technologies provide an unmatched superiority to study the vegetation cover change over large or middle scale areas (Zhang, 2001). A few large area studies of vegetation cover dynamics utilizing remote sensing data over a long time period have been made in the arid western China. However, most recent studies in this region focused primarily at local scales (Wang et al., 1998, Liu et al., 2001, Meng et al., 2003, Zhao et al., 2004). Moreover, these studies (Ma et al., 2003, Yan et al., 2003, and Piao et al., 2001) on vegetation change in the arid western China were less quantitative as these studies focused primarily on the spectral properties of this region. There were limited number of quantitative studies but their study areas were primarily in desert oasis ecotone (middle and high grassland cover). The oasis ecotone is the core area of human productivity and activity in the arid lands.

Studies on vegetation changes over time focus on the spatial dynamics as well as on the total areal changes of different vegetation types. Changes in areas over space and time directly are a collective result of many causes, ranging from natural climate extreme events to human activities. At local scale, the spatial pattern is often not enough to represent changes at large scales. Only when we look at changes at a regional scale can we understand vegetation changes and their tendencies of an entire ecosystem. Continual expansion of the desert areas indicate that the ecosystem's environment has been degraded, while shrinking of desert would suggest an improvement of the ecosystem environment. Therefore in western China, it is necessary to quantitatively analyze the spatial and temporal patterns of different vegetation types over a period of time. In this study, we first derived fractional vegetation cover (FVC) images from NOAA/AVHRR time series data from 1982-2000 and used the areal division method (Shi, 2003) to study the spatial and temporal patterns of land use and land cover change. The temporal changes in fractional cover for different regions within the western China were analyzed to arrive at the patterns and drivers of these changes.

Study Area The northern boundary of the study area follows the Altai watershed (Appendix 1, Fig.1). The Yin Mountains along the border between China and Mongolia bounds the study area on the east. The southern boundary ranges from south of the Tianshan Mountains to the Helan Mountains in the Kunlun Mountains. The western part of China is characterized by mountains (Tianshan, Kunlun, and Altai) and arid basins. The precipitation ranges from 20mm in the arid basins to 250mm in the mountain regions, while the annual temperature ranges from 0 to 50^{o}C. There is a general gradient in precipitation along the longitude ranging from 200-250mm in the eastern part of the study area to 20-50mm in the western part. There is also a latitudinal gradient at the elevation of 300m-800m that ranges from 300-500mm in Jungger Basin in the north to 100mm-1500m in Taripan Basin in the south. Most of rainfall events occur in the summer time and are so spatially heterogeneous that some areas receive no rains in years.

Vegetation distribution is primarily a function of elevation. On the Altay Mountains (north of Part I in Appendix 1, Fig. 1), the desert areas are distributed below 800m in elevation. On the Tianshan Mountains there is a markedly difference in vegetation types between north and south slopes. The north slopes (shaded slope) are primarily needleleaf forests while on the south slopes are steppes. The deserts are located below an altitude of 1700m on the north slopes and above 2400m on the south slope. On the south Xinjiang (Part III) and the north slopes of Kunlun Mountains and Alijin, the deserts are located primarily below an elevation of 3200m (Academic Research Xinjiang Term of Chinese Academy of Science & Institute of Botany of Chinese Academy of Sciences, 1978).

The major human land uses include rangelands, deserts, forests, oasis, and urban. There is a narrow band of oases around the mountains between forest/snowcaps and deserts, fed primarily by the seasonal snow melting from mountains. The major agricultural activities include grazing (70%) and farming (30%). This region is rich in petroleum from the basins and rich in minerals from the mountains. The major economy is petroleum production and livestock. This region is also a major tourist attraction as it has preserved its natural beauty due to sparse population and limited economic developments in China. With the implementation of the Grand West Development Strategy by the Chinese central government since the later 1990s, this region has been identified as one of the most desirable areas for near future development. In recent years, the area has seen increased population and urbanization as investors come in for petroleum and livestock/dairy productions from the coastal region.

Data Processing and Classification 3 In order to analyze the changes in vegetation dynamics in the past 20 years, a time 4 series of fractional vegetation cover (FVC) for the period of 1982-2000 was constructed 5 using the AVHRR data (8km spatial resolution) from the University of Arizona (Zeng et al, 6 2000). Ancillary data used in the analysis included a DEM with a 1 km spatial resolution, a 7

Chinese environment resource dataset with a scale of 1:4000000, and a world water 8 borderline provided in the ENVI software. These images were geometrically registered 9 using more than 60 ground control points (GCPs) that were previously collected. The images were then transferred to the ARC/INFO grid format for subsequent processing using ARC/GIS 8.3 software.

Table 1. Classification Rule in the Three Zones of the Study Region

Zones (Figure 1)		Codes	Range of FVC Value	Vegetation types	Vegetation cover
Plain	Low altitude plain area 1.Plain of North Xinjiang DEM<=1300m 2.Plain of East South Xinjiang and Hexi Corridor—Alxi Plain, DEM<=2000m	T1	0-0.045	Desert, Gobi without vegetation	<10%
		T2	0.046-0.095	Plain low grassland	10%-30%
		T3	0.096-0.23	Plain middle grassland cover	30%-50%
		T4	0.231-0.445	Plain high grassland	50%--70%
		T5	0.456-1	Oasis, pasture, meadow	>70%
Al tiplano	3.Qaidamu High Basin 3300m>=DEM>2 000m	T11	0.456-1	Meadow, High Basin Oasis	>70%
Mountain	Mountainous 1.Mt. of North Xinjiang DEM>1300m 2.Mt. of East South Xinjiang and Hexi Corridor—Alxi Plain, DEM>2000m 3.Qaidamu High Basin DEM>3300m	T6	0-0.045	Mountain without vegetation	<10%
		T7	0.046-0.095	Mountain low grassland cover	10%-30%
		T8	0.096-0.23	Mountain middle grassland cover	30%-50%
		T9	0.231-0.445	Mountain high grassland cover	50%--70%
		T10	0.456-1	Mountainous steppe, forest	>70%
	Water area	T0	1.11	Water area and glaciers	0%

Based on previous studies and reports (Academic Research Xinjiang Term of Chinese Academy of Science & Institute of Botany of Chinese Academy of Sciences, 1978; Editorial Board of Vegetation Map of China, China Academy of Sciences, 2001; Pan et al., 2001, and Shi, 2003a, 2003b), the study area was further divided into three zones: Altai-West Tianshan zone (I), East Tianshan–Tarim Basin zone (II) and Qaidamu high basin-Alxa desert zone (III) as shown in Figure 1. These sub-regions were divided based primarily on the characteristics of the vegetation type and geographic characteristics (altitude, longitude and latitude).

Different classification methods (supervised maximum likelihood and unsupervised methods) were used for different sub-regions/zones according to their ecological and biophysical properties as shown in Table 1. Since there are large differences in total areas between different vegetation types (for example, the desert occupies about 70% of the total study area while oasis makes up approximately 10%), we used the phenological information to show the vegetation change and to smooth the data in the subsequent change analysis. The vegetation classification maps produced for the research area are shown in Figures 2, 3, 4, and 5 (Appendix 2, Fig. 2,3,4,5). These classification maps were used in change detection analysis by examining their total areas from 1982 – 2000 for each vegetation cover type.

4. Change Analysis and Results 5 In the Hexi Corridor-Alxi Plain the total oasis and grassland areas went through little 6 changes during the 18 years from 1982-2000, as only 70 pixels changed (Appendix 3, Fig. 6), which is 7 equivalent to a total area of 4200km^2 (8km x 8km x 70). The middle grassland cover increased by around 300 pixels (~20,000km^2), while the low grassland cover and the desert decreased by about 1200 pixels (~80,000km^2). For the mountain vegetation type change in the Qaidamu High Basin, all of the change was much less than in the plain vegetation types (Appendix 3, Fig. 7). Interestingly, the amount of desert in this area is in an upward trend while the meadow areas had a downtrend from 1982-2000. Additionally, the extent of low and middle cover grassland areas decreased whereas the high cover grassland areas increased by approximately 50 pixels (~3,000km^2).

In the north Xinjiang there was a decrease of 223 pixels (15,000km^2) in the desert area and of 177 pixels (12,000km^2) in the high cover grasslands (Appendix 3, Fig. 8). Moreover, the low and middle grassland cover almost disappeared. In contrast, the areas of oasis showed a steady growth throughout 1982-2000 with 414 pixels (29,000km^2).

The desert, low, and middle grassland covers exhibited a stability with little changes (less than 50-pixel range) for the mountain vegetation type in the north Xinjiang (Appendix 3, Fig. 9). In contrast, the high grassland cover and mountain forest changed equally in total areas (forest areas increased while the high grassland cover decreased). The desert and low grassland covers of the plain vegetation type in south Xinjiang did not have a significant change over the time period of this study (Appendix 3, Fig. 10). While both the middle and high grassland covers decreased, the oasis increased from 1982 to 2000.

Significant changes in vegetation types were found to be in the mountain vegetation types in the south Xinjiang (Appendix 3, Fig. 11). The desert and the low grassland covers had the largest undulating change while the middle grassland change was in the opposite direction. High grassland and forest covers had a tendency of increases from 1982-2000.

Discussion In the plain areas, there was an overall slight decrease in deserts from 1982 to 2000, which is more obvious in the north Xinjiang. Deserts and low grasslands in the south Xinjiang and Qaidamu High Basin showed an increasing trend, resulting a balance in the total area changes. One reason for the decrease in desert areas in north Xinjiang is likely 6 related to human activities. From 1955-1970, residents in Xinjiang developed new farms on the natural oases, and then abandoned them due to either water shortage or salinity problems. Regrowth of the natural vegetation occurred after these lands were abandoned. These observations agree with well with our field surveys in this study. The fact that the climate in north Xinjiang is propitious to vegetation growth may be another reason for the decrease in the total desert areas (Hu et al, 2001). An additional characteristic in the plain is the continued increase in the total man-made oases, especially in Xinjiang. There were no significant increases in the Hexi Corridor-Alxi Plain. This contrast between the two sub-regions is most likely related to the quality of the farmlands. Xinjiang has the one of the highest quality areas for the production of cotton and the quality of the cotton in this sub-region is much higher than those in other sub-regions. Consequently the cotton farmland expanded quickly near the existing oases to boost the economic profits. In the Hexi Corridor-Alxi plain, the major crop in these old oases is wheat. Since the price of wheat has not changed and its value is not as competitive as cotton, there was not motivation to expand wheat production, resulting in little changes in wheat dominated oasis areas.

The vegetation on the mountains was less influenced by human activities and, therefore, the change in vegetation covers in this region most likely reflects the natural variations such as climate change over the study period. Owing to the similarities in the desert, low and middle grassland covers between the mountain region in south Xinjiang and Qaidamu High Basin, it is possible that the same factors caused the changes in the Qaidamu High Basin and the mountains in south Xinjiang. The forest areas increased in Xinjiang due to both human activities and natural climate changes. The logging activities are now regulated by the governments when new policy was in the later 1980s. This resulted in a reduced logging and deforestation. In addition, the regional climate changed over the region and the precipitation increased by approximately 10% over the study period, especially in the northern Xinjiang (The National People's Congress of the People's Republic of China, 1979; Hu Ruji et al, 2001). The coupled consequence is an increase in forested areas in the north Xinjiang. However, in Qaidamu High Basin, the total meadow areas decreased and the amount of desert increased, indicating that the vegetation has degraded in those regions, as there was little increases in precipitation and logging regulations were not enforced.

There was a very strong inter-transitional relationship among the oasis, the high and the middle grassland in the plain areas. In the mountain areas, the same relationship was found to occur between the desert, the low and middle grassland. Moreover, the relationship was found to be the strongest between the high grasslands and forest meadows. Analysis of the changes in vegetation suggested an obvious increasing trend in oases in the plain areas. Particularly from 1980 to 1990, during the period of "rural land reform" olicy in place, oasis areas expanded rapidly. The farmland increased as the cost of the decreases in the high and middle grasslands. In arid and semi-arid regions, ecological functionality of the natural oasis systems is superior to the man-made oases. However, little attention has been paid to the differences between natural and man-made oases. Clearly, the results from this study suggest that the human activity was one of the most important factors resulting in changes in vegetation types in the arid lands of Xinjiang. In the plain areas, man-made oasis is relatively stable while the middle and high grasslands continually decreased. The man-made oasis systems are increasingly subjected to desertification due to reductions in regional precipitation and in ground water supplies. It is important to ensure that the oasis is stable as there is a need to maintain a balance between desert, ecotone and oasis (Pan, 2001). At the same time, it is also important to protect the middle and high grasslands. By protecting the ecotone the oasis can be protected and this may be the best way to sustain the arid and semi-arid lands while maintaining economic development.

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============================ **ДОКЛАДЫ** ===================================

ОТНОСИТЕЛЬНОЕ ИЗМЕНЕНИЕ ОКРУЖАЮЩЕЙ СРЕДЫ В АРИДНЫХ ЗОНАХ ЦЕНТРАЛЬНОЙ АЗИИ ПО ДАННЫМ НАБЛЮДЕНИЙ ЗА СОСТОЯНИЕМ ЗЕМЛИ И НАБЛЮДЕНИЮ ПОЧВ

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Отдел географии и планирования,
Государственный Университет Грэнд-Вэлли
1150 ОуСейбл Холл, 1 Кампус драйк
Оллендэил, MI 49401, США

Климатические изменения свидетельствуют о том, что окружающая среда аридных зон может подвергнуться радикальным изменениям в результате глобального потепления и растущей концентрации углекислоты в атмосфере.

Анализы временных и пространственных колебаний NDVI, полученных NOAA метеорологическими спутниками с 1981 до 2001 гг. вместе с температурой и данными выпадания осадков метеорологических станций показали огромные изменения в ландшафтном покрове Центральной Азии в течение последних двух десятилетий. NDV1 является необходимым индикатором для определения растительного покрова, производства зеленой биомассы и поэтому, тесно связана с климатическими факторами. Изменчивость этого показателя взаимосвязана с изменением осадков и температуры в этом средне-опустыненном регионе. Согласно нашим предварительным данным, в центре аридных земель наблюдалась тенденция расширения растительного покрова в период 1982-1996 гг., за исключением территории окрестностей Аральского моря, сменившаяся обратной тенденцией в период 1996-2001 гг. С начала 1980-х годов более чем 2/з территории аридных зон в Центральной Азии, подверглись расширению зеленого покрова приблизительно на 10%. Эти изменения, происходящие в растительном покрове связаны с изменением количества осадков и, вероятно, климатическими различиями, связанными с увеличением растительности и биогенетических слоев вследствии накопления в атмосфере CO2. Большая неопределенность существует в изменчивости наблюдаемой NDVI. Указанный факт является ответной реакцией флоры и фауны на глобальные изменения климата, интенсивного сельского хозяйства с применением орошения, оптимизацией выпаса скота.

ENVIRONMENTAL CHANGES IN ARID CENTRAL ASIA INFERRED FROM REMOTE SENSING DATA AND GROUND OBSERVATIONS.

© 2005. E. Lioubimtseva

Geography and Planning Department, Grand Valley State University
1150 Au Sable Hall, 1 Campus Drike
Allendale, MI 49401, USA
Lioubime@gvsu.edu

Introduction

Meteorological records indicate that arid and semi-arid zones of Central have experienced a significant warming signal since the last decades (Neronov, 1997; Chub, 2000; Lioubimtseva, 2004). Regional responses to the global warming trend include melting of the high-mountain glaciers in the Tianshan and Pamir, dramatic lake-level fluctuations, changes in the river' discharge, species migration, and numerous changes in ecosystem dynamics and land-use. The arid Central Asia region is very vulnerable to human disturbances and regional climate changes, because ecosystems in the region may be the first to reach tipping points under current human disturbances and climate change (Lioubimtseva and Adams, 2004).

To fully understand the impact of human activities, it is also necessary to consider the extent to which anthropogenic effects have modified the background level of carbon storage, and whether change in the intensity of either process has any evident potential to take up or release carbon from the desert-zone carbon reservoir. There is significant uncertainty regarding the possible impacts of global climate change on the sequestration of carbon in the vegetation and soils of the arid zones in general, and in those of Central Asia in particular. It is possible that global climate change could result in significant changes in carbon reservoirs in these areas. Estimates of the carbon pools in the desert soils are still very uncertain (Lioubimtseva and Adams, 2002; Lioubimtseva et al, 2005).

Current and predicted climate trends

The Central Asian arid region comprises the Turan Lowland and the southern margin of the Kazakh Hills (Figure 1) and is bounded by the Middle Asian mountains on its southern and southeastern edges.

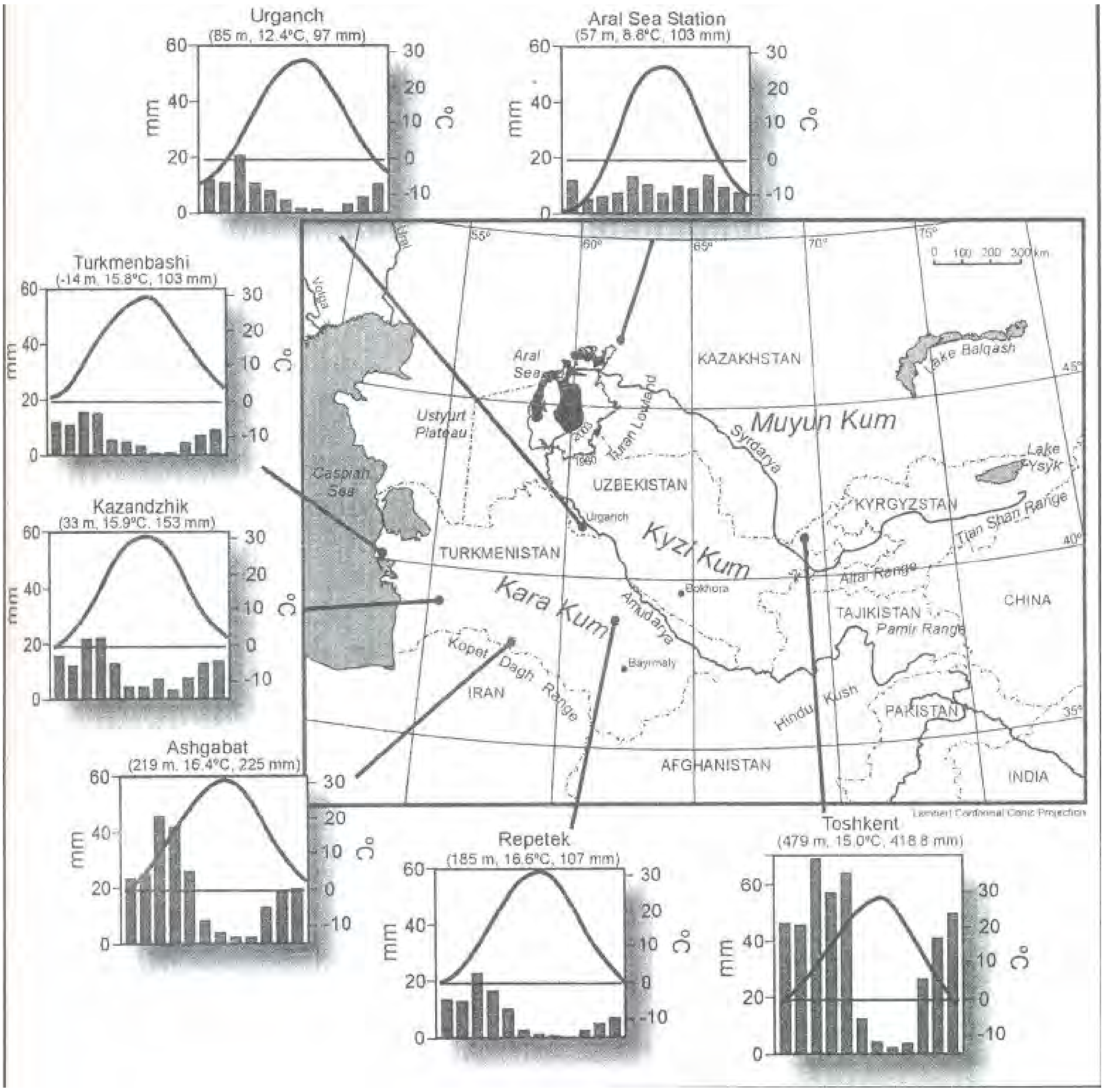

Fig. 1. The study region and its climate

In the southwest the somewhat lower mountains of the Kopet Dagh allow monsoon precipitation to reach the western slopes of the Tian Shan and Pamir-Alaï ranges. To the north the Turanian plain descends progressively northward and westward and opens out towards the Caspian lowland. The northern boundary of this vast arid zone is rather poorly defined but it lies at approximately 48°N. Continental climate of this region implies that summers are hot, cloudless and dry, and winters are moist and relatively warm in the south and cold with severe frosts in the north. Precipitation has a distinctive spring maximum, which is associated with the northward migration of the Iranian branch of the Polar front. Most frequently rain is brought by the depressions which develop over the Eastern Mediterranean, migrate north-eastwards, and regenerate over the Caspian Sea.

The IPCC report Regional Impacts of Climate Change, 2001 addresses Central Asian republics in Chapter 7 “Middle East and Arid Asia” but provides very limited information about climate change in arid Central Asia (IPCC 2001). “There were no discernible trends in annual precipitation during 1900-95 for the region as a whole, nor in most parts of this region” (IPCC 2001, Chapter 7). The aridity index shows no consistent trends for Central Asia as a whole (IPCC, 2001). The report does point out a likely 1-2 degree C/century temperature increase for Central Asia.

Meteorological data series show a steady increase of annual and winter temperatures in this region since the beginning of the past century (Neronov, 1997, Chub, 2000; Lioubimtseva et al., 2005). Unfortunately only a few stations in central Asia have a period of observations spanning more than a century. Most stations have records for a relatively short time, roughly 50-60 years. In addition, many meteorological stations in the region practically stopped functioning after the collapse of the USSR as a result of severe funding cuts (Chub, 2000).

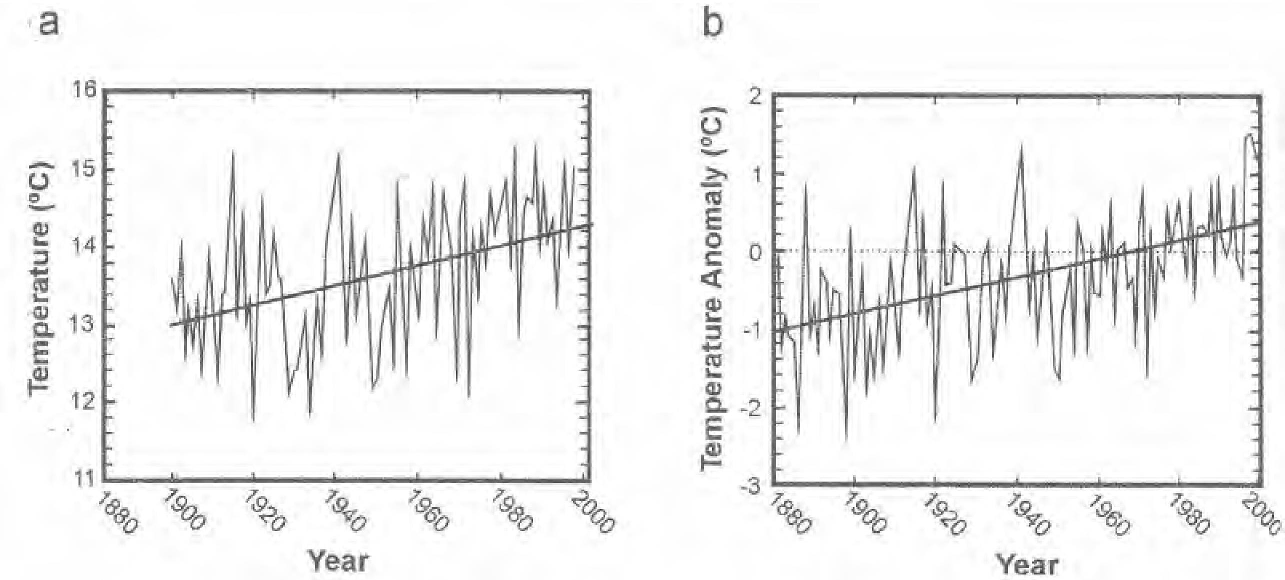

Fig. 2. Temperature increase from 1900 to 2000

a. Toshkent station (adapted from Chub, 2000)

b. temperature anomaly for 1880 to 2000 for arid zones of Central Asia (based on GHCN dataset, Peterson & Vose, 1997).

Climate models predict that the temperature in arid Central Asia will increase by 1-2° C by 2030-2050, with the greatest increase in winter. Precipitation projections vary from one model to another and projected changes in the aridity index for different model runs show no consistent trend for this region (Figure 3). Some models project greater aridity in the future and some predict less; it is becoming increasingly apparent that climate change modelling in arid zones is extremely uncertain, partly because of the extreme natural variability (both temporal and spatial) of the desert climate and partly because of inherent uncertainties in global and regional climate modelling (Lioubimtseva and Adams, 2004). Atmospheric dynamics are known to be very sensitive to natural climate variability at relatively short time-scales and the effect of short-time variability on longer (decadal-to-millennial) time-scales are not fully understood.

Both theoretical considerations and numerical models have shown a significant sensitivity of the climate of arid regions to vegetation distribution. Ground-cover parameters can significantly alter the modelled climate (Zolotokrylin, 2002; Wang and Eltahir, 2000).

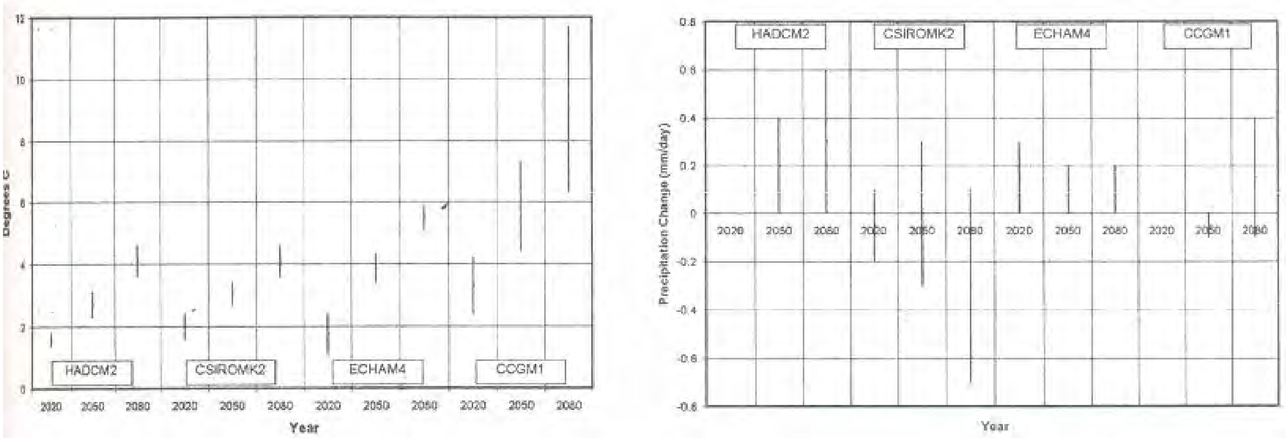

Fig. 3. GCM scenarios for arid zones of Central Asia, 2020 to 2080 (from Lioubimtseva et al., 2005).
a. Temperature range (degrees C).
b. Precipitation range (mm per day).

Climate change scenarios, unfortunately, do not incorporate regional controls on climate. The impacts of the extensive redirection of montane and lacustrine water resources to irrigated agriculture in Central Asia and the degradation of the Aral Sea remain unmeasured in current climate models yet may be of significant importance in regional climate change. Although it is clear that both observed and predicted climate changes might be partly caused by global climate change and partly by local anthropogenic processes it is extremely difficult, if not impossible to delineate the boundary between these two factors.

Remote sensing approach

In the regions with limited amount of ground observations long temporal series of remote sensing data offer a very useful and often the only possible approach to climate change. Such monitoring techniques are based on the estimation of the statistical relationship between climate aridity and vegetation phytomass estimations from satellite imagery (Kogan, 1995; Lambin, 1997; Nicholson et al., 1998). Most of remote sensing research on arid lands has been focused on climate change in the Sudan-Sahelian zone of Africa and the Western USA. Zolotokrylin (2002) developed an new empirical aridity index for Central Asian deserts and semideserts, which can be defined as a duration of the period with a normalised difference vegetation index (NDVI) less than 0.07. This indicator reflects the zonality of heat exchange between arid land and atmosphere as the relation of radiation and evapotranspiration mechanisms in the regulation of thermal conditions of soil surface and the lower layer of atmosphere (Zolotokrylin, 2002) .

Methodology

This study is based on the analysis of satellite imagery from the Pathfinder Advanced Very High Resolution Radiometer Land dataset. Parameters produced as a part of this dataset include reflectances and brightness temperatures derived from the five-channel cross-track scanning AVHRR aboard the NOAA Polar Orbiter 'afternoon' satellites (NOAA-07: Jul 81 to Jan 85, NOAA-09: Feb 85 to Oct 88, NOAA-11: Nov 88 to Sep 94, and NOAA-14: Jan 85 to Oct 01), along with a derived Normalized Difference Vegetation Index (NDVI), cloud and quality control indicators, and ancillary data. These data are derived from the NOAA Global Area Coverage (GAC) Level 1B data spanning a period of more than 20-years (1981-2001).

Pigments in green leaves (notably chlorophyll) absorb strongly at red and blue wavelengths. Lack of such absorption at near-infrared wavelengths results in strong scatter from leaves. The contrast between red and near-infrared reflectance of vegetation is captured by NDVI, a commonly used greenness index (near infrared-RED)/(near infrared + RED), which is often used as a proxy for biomass, net primary productivity, and leaf area index (Tucker, 1979; Kogan, 1995; Qi et al., 2000). Although NDVI poses some serious problems and more advanced indices and NDVI modifications have been developed during the past decade, NDVI still represent a very useful tool for landcover monitoring since it is robust, easily available from the AVHRR and other sensors, can be easily ground-truthed and demonstrates good correlation with the amount of photosynthesizing vegetation. Advantages and disadvantages of NDVI have been thoroughly discussed in the international remote sensing literature during the past decade (Qi et al., 2000; De Beurs and Henebry, 2004).

Six hundred ninety eight (698) 10 -day maximum value composites available since July 10, 1981 to September 30 2001, gridded at a resolution 8 km by 8 km were used to establish the NDVI temporal trends in arid central Asia. There is a permanent data gap in 1994 from the middle of September to the end of December due to satellite failure. September 30, 2001 is currently the last day of data available.

Simple statistical analyses of these data series involved 1) review of temporal variations revealed in the 10-day and monthly NDVI composites with particular focus on annual trends in spring NDVI (associated with precipitation peaks), 2) analyses of statistical relationships between NDVI and precipitation for four key area (Eastern Kara Kum, Plateau Usturt; Central Kyzyl Kum, and an area around and eastward from the Aral Sea), and 3)computation and analyses of the spatial and temporal patterns of an empirical aridity index, derived from the NDVI.

Results and discussion

Smoothed NDVI series revealed a substantial increase in NDVI between 1986 and 1994 with a very prominent peak in 1993-1994, followed by a slight decline. Interestingly, this trend is well observable in all parts of Central Asia, despite the great variability the local landscape and meteorological conditions (Figure 4). The 1993-1994 greenness peak has been reported also in other vegetation indices- based studies in the adjacent arid and semi-arid regions of Eurasia (DeBeurs and Henebry, 2004; DeBeurs et al., this issue; Bajargardal and Karnieli, this issue). The reason of this peak, however, is still unclear. While many studies attribute this increase in NDVI and related indices to higher vegetation biomass due to higher levels of precipitation in early 1990s (Bayarjargal and Karnieli, 2004; Zolotokrylin, 2002; Kharin et al., 1998), others suggest that the most plausible explanation of higher NDVI might be an artifact caused by miscalibration of the NOAA-11 imagery (DeBeurs and Henebry, 2004).

Our study revealed fairly strong correlation between NDVI and precipitation for most of the region in the 1980s and 1990s that is in a good agreement with the earlier NOAA-based studies in Uzbekistan and Kazakhstan (Kharin et al., 1998; Zolotokrylin, 2002).

Based on the assumption of the steady relationship between NDVI and precipitation a simple empirical index of aridity derived from NDVI was used in order to address the spatial and temporal climate variability:

A= $NNDVI<\alpha$ /T, where N is number of 10-day intervals with NDVI less than a threshold value α (climate-related variable that was set to 0.07 for arid Central Asia) and T is a number of 10-day intervals between April 1 and October 31 during the period of observation. This index of aridity, computed both for the 1980s and 1990s reveals a decrease of aridity in most of Central Asian region except for the Aral Sea area (table 1). The increase of the number of 10-day intervals with arid NDVI in a vicinity of the Aral Sea is apparently caused by the severe human-induced desertification of this area and is well confirmed by the ground observations.

Table 1 Changes in the NDVI-based aridity index

Years/location	East Karakum	Usturt	KyzylKum	East Aral
1981-1990	0.033854	0.035024	0.029463	0.023627
1991-2000	0.028701	0.025141	0.038037	0.044112

One must keep in mind, however, that compare to other biomes, desert and semi-desert landscapes are featured by a very sparse vegetation cover and that more than 65% of the surface reflectance signal in this very coarse-resolution pixel data is coming not from vegetation but from the soil. If one assumes that the barren soil signal is fairly constant and the data misregistration from different satellites is probably not significant to cause this trend, we should assume that the revealed NDVI difference should be attributed to vegetation changes. On the other hand, one should also ask a question, how barren is barren soil in the desert, or in other words, what is the proportion of the observed NDVI signal coming from the microphytic communities (mosses, fungi, algae and cyanobacteria) on the soil surface compare to the signal of vegetation?

Microphytic communities form biogenic crusts on the soil surface varying from a few millimetres to several centimetres in thickness and play a significant role in the desert ecosystems controlling such processes as water retention and carbon and nitrogen fixation in soils. In the Kara Kum desert of Turkmenistan the accelerated growth of such biogenic crusts has been observed during the past 40-50 years and usually has been attributed to the undergrazing caused by the decrease of the wild fauna and insufficient pressure on the desert rangelands. It is possible, however, that the main reason for the accelerated growth of “black mosses” in the Kara Kum is a response of microphytes to increasing concentrations of CO2 in the atmosphere (Lioubimtseva et al., 2005). Remote sensing data series including the blue channel of electromagnetic spectrum (such as Landsat TM and VEGEATION-SPOT), which is absent in AVHRR NOAA, might provide more insights on delineation of the signal produced by the biogenic crusts from the one of the higher vegetation (Karnieli et al., 1999). Unfortunately VEGETATION imagery of the spatial resoution comparable to that of AVHRR is available only since 1998.

The CO2 fertilisation effects not only microphytic communities but also higher vegetation. An increased atmospheric CO2 concentration has direct and relatively immediate effects on two important physiological processes in plants: it increases the photosynthetic rate, but decreases stomatal opening and therefore the rate at which plants lose water. The combination of these two factors, increased photosynthesis and decreased water loss, implies a significant increase of water efficiency (the ratio of carbon gain per unit water loss) and productivity and a reduction in the sensitivity to drought stress in desert vegetation as a result of elevated atmospheric CO2 (Smith et al., 2000).

No regional modelling studies have been conducted in the Central Asian region but global biogeography models (Melillo et al., 1993; Woodward et al., 1998) predict relatively strong responses of arid ecosystems to global climatic change.

The Kara Kum and Kyzyl Kum deserts of Central Asia are dominated by vegetation with the C3 photosynthetic pathway with only few C4 and CAM species. It is often expected that plants using the C3 photosynthetic pathway will respond more strongly to raised CO2 than species with the more water-efficient and CO2-efficient C4 photosynthetic system. The significance of different photosynthetic pathways in the adaptation of perennial plants to life in extreme desert environments is still hotly debated (Graybill and Idso, 1993; Whitford, 2002; Grünzweig, and Körner, 2000). Most publications on this subject are based on chamber experiments and the recent Free-Air CO2 Enrichment experiments studying responses of desert vegetation to increased CO2 levels conducted in the south-western USA where desert vegetation cover is dominated by C4 species (Smith, 2000; Huxman et al., 2000).

Conclusions

The preliminary results of this study suggest that there have been a greening trend in arid central between 1982 and 1995 with a prominent peak in 1994, followed by the opposite trend between 1996 and 2001. Since the early 1980s more than 70% of arid zones of Central Asia have become greener by about 10 %. These vegetation changes are due to precipitation changes and probably, to easing of climatic constraints to growth of plants and biogenic crusts caused by CO2 increase in the atmosphere.

The complexities of precipitation changes, vegetation-climate feedbacks, and direct physiological effects of CO2 on vegetation present particular challenges for understanding and modelling climate change in temperate arid regions. Great uncertainties exist in the prediction of responses of arid landscapes of Central Asia to elevated CO2, as well as to global and regional, natural and human-induced climate change.

There has been a general warming trend in Central Asian republics on the order of 1-2 degrees C since the beginning of the 20th century that might have a strong potential impact on the regional temperature and precipitation regimes and also on natural ecosystems, agricultural crops and human health.

Climate change projections in this region vary from one global model to another. Despite the great progress in global climate modelling, the GCMs give very variable results, with large spatial differences in the areas forecast to receive higher or lower precipitation. The lack of integration of such factors as dust aerosols, biophysical and biochemical feedbacks caused by land-cover changes, as well as the regional factors of human-induced climate change, such as irrigation, are the major sources of uncertainties. For example, the dust aerosols from the drying Aral Sea bottom might have a very significant impact on regional climate but they are not taken into account by the models.

Projections based on biogeographic models suggest considerable changes in desert and semi-desert vegetation due to a combination of greenhouse-related climate change and direct physiological CO2 effects on vegetation, such as changes in photosynthesis and water-use-efficiency over the coming century. This could likewise have implications for crop growth in desert-marginal areas, favouring greater productivity, and perhaps increase productivity and biomass of natural desert vegetation and soil organic matter. However, the very limited number of CO2 enrichment experiments in the Kara Kum and Kyzyl Kum do not always confirm this thesis. Moreover, the results of CO2 fertilisation experiments in other arid regions of the world, such as the Negev desert in Israel (Grünzweig and Körner, 2000) and Mojave desert in the US (Smith et al., 2000) are rather mixed – which only contributes to the uncertainty about the implications of the doubled CO2 concentrations for desert ecosystems. The accelerated growth of biogenic crusts (observed during the past 40-50 years) in this arid region might be a response of microphytes to increasing concentrations of CO2 in the atmosphere. However, because such responses occur only on the undergrazed desert rangelands it is still unclear if the CO2 increase really is the major cause or such growth, rather than land-use change.

One of the major sources of uncertainty about vulnerability and impacts of climate and land-cover changes in arid lands of Central Asia is the lack of reliable and accurate data on climate and ecosystems necessary for regional climatic and biogeographic modelling. While the local responses to global climate change have been a source of major uncertainties, it is clear that there have been very intensive human-induced regional climate and environmental changes in Central Asia, primarily associated with massive irrigation schemes, the desertification crisis in the Aral Sea area, and changes in the grazing pressure on desert rangelands. Local and regional human impacts in arid zones can significantly modify surface albedo, as well as water exchange and nutrient cycles that could potentially have impacts on the climatic system both at the regional and global scales. On the other hand, improved management techniques can increase the carbon sequestration capacity of semi-desert rangelands and arable lands.

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============================ **ДОКЛАДЫ** ====================================

ИНДЕКСЫ NDVI И LST ПРЕДСТАВЛЕННЫЕ NOAA-AVHRR ДЛЯ ВЫЯВЛЕНИЯ ЗАСУХ В МОНГОЛИИ

© 2005 г.   Ю. Баяржаргал, А. Карниели

Лаборатория дистанционных методов,
Институт пустынь Университета Бен-Гуриона,
Нежев, Седе Бокер Кампус, 84990, Израиль

Временно-пространственные колебания нормализованного разностного вегетационного индекса NDVI, температуры поверхности земли LST получены NOAA - AVNRR датчиками в течение вегетационного периода; определена динамика накопления фитомассы растительности. Опыты проведены в 1992-1999 гг. и проанализированы в экосистемах полупустынь и пустынь Монголии. Высокая негативная связь между NDVI и LST дает возможность общего комплексного использования этих переменных для контроля над параметрами засухи. Было проведено сравнение между двумя указателями NDVI. Проанализировано отношение между LST и NDVI (LST/NDVI), в результате чего, выявлены функционирования разных пространственных моделей при неодинаковом ускорении режимов. Более того, различия были обнаружены между индексами и традиционно обоснованными данными метеорологических наблюдений.

NOAA-AVHRR DERIVED NDVI AND LST FOR DETECTING DROUGHTS IN MONGOLIA

© 2005.   Yunden Bayarjargal and Arnon Karnieli
The Remote Sensing Laboratory, Jacob Blaustein Institute for Desert Research, Ben Gurion University of the Negev, Sede Boker Campus, 84990, Israel
E-mail addresses: yub@bgu.ac.il; karnieli@bgu.ac.il

Introduction

Satellite-derived early warning of droughts and assessing their severity are becoming popular in wide-ranging disaster monitoring and climate change studies. Though drought is a complex phenomenon, it has been defined by the meteorological community as a period of abnormally dry weather, which results in decrease of vegetation cover (Tucker & Choudhury, 1987; Heim, 2002). Drought can be ended when a region receives necessary amount of precipitation in a certain period (e.g., weeks, months), and thus the decreased vegetation cover might be recovered (Nicholson et al., 1998; Prince et al., 1998). Therefore, start, end and the effect of drought on the vegetation in wide areas can be estimated by monitoring the dynamics of vegetation cover over time by using remote sensing change detection method.

Numerous researchers investigated the possibility of assessing and monitoring droughts in semi-arid environments (e.g., Gutman, 1990; McVicar & Jupp, 1998) using indices derived from Advanced Very High Resolution Radiometer (AVHRR) onboard the National Oceanic and Atmospheric Administration (NOAA) satellites. The sensor has been orbiting around the globe since the late 70th with 5 spectral channels. The sensor’s data (1981-present) is archived and distributed by the National Aeronautics and Space Administration (NASA). In the past-decades, the Normalized Difference Vegetation Index (NDVI, Tucker, 1979) calculated from the reflected channels of the NOAA-AVHRR were developed and successfully used for assessing droughts (Tucker & Choudhury, 1987). Moreover, several authors used the ratio between the NDVI and land surface temperature (LST/NDVI) in order to improve estimation of vegetation state and condition with respect to droughts or stress situations (McVicar & Bierwith, 2001; Karnieli & Dall'Olmo, 2003; Bayarjargal et al., 2000). The reason for using the combined NDVI and LST data is based on their strong negative correlations in the arid environment and the hypothesis that increasing temperatures are acting negatively on vegetation vigor and consequently are causing stress (Nemani & Running, 1989; Lambin & Ehrlich, 1996; Karnieli et al, 2005).

The aims of this paper are to study the spatial-temporal variations of the NDVI and LST and to compare the effectiveness of the spaceborne drought-indices during the growing period over the Desert-Steppe and Desert ecosystems of Mongolia, also with respect to the traditional ground-observed weather data.

Study area and dataset

The research objective was implemented on the Mongolia's Desert-Steppe and Desert ecosystems that cover more than 40% of the country (Figure 1). The study area includes the Great Lakes Depression, the Valley of Lakes, the Gobi-Altai Mountains, and the Plateau of Eastern Gobi. Low grasses, semi-shrubs, and woody plants are the dominant vegetation of the study area, and peak biomass occurs in the late summer (Batima et al., 2000). The annual mean air temperature is about 4°C. July is the warmest month with average temperature of 25°C and maximum temperature can reach 35-45°C (Natsagdorj, 2000). The total annual precipitation is about 75-150 mm and less than 75 mm in the Desert-Steppe and Desert ecosystems, respectively. About 75-85% of the precipitation falls during the three summer months, from June to August. It was reported that the frequency of drought in the Gobi region during the spring and summer has been increased from 1-2 to 3-4 times every five years (Shiirevdamba, 1999). Thus, the Desert-Steppe and Desert ecosystems of Mongolia were chosen as test area for studying the spatial-temporal variations of the NOAA-AVHRR derived NDVI and LST, and for comparing their effectiveness in drought detection.

The Pathfinder AVHRR Land (PAL) archived NDVI and brightness temperatures in channel 4 and channel 5 were used in this study. The LST was computed from the brightness temperatures by split-window algorithm (Price, 1984; Qin and Karnieli, 1999). Dataset were composed of monthly maximum values for vegetation growing season (April-September) over the period of 1982-1999, in the Geographical projection with spatial resolution of 0.1 x 0.1 degrees in latitude and longitude. The PAL dataset was generated from the NOAA satellite 7, 9, 11, and 14 (Agbu & James, 1994) and was obtained from the Goddard Space Flight Center (GSFC) Distributed Active Archive Center (DAAC, WWW). The PAL dataset were used for many studies of global vegetation (e.g., Shabanov et al., 2002; Buermann et al., 2002), and changes in land cover characteristics (e.g., Anyamba and Eastman, 1996; Young and Wang, 2001; Henebry, 2004; Lioubimtseva, 2004; and more).

Analysis

This study intends to evaluate inter-annual variations and spatial distributions of NOAA-AVHRR derived NDVI and LST over the Desert-Steppe and Desert ecosystems of Mongolia, during 18-year period. Data processing was limited to the vegetation-growing period (VGP) that lasts for 6 months from April to September, since only the warm-summer season allows vegetation development in the region after the harsh winter. The VGP was divided into three sub-periods of phenology: the beginning (April-May); the middle (June-July); and the end (August-September).

The change detection technique – Change Vector Analysis (CVA) – that was adapted to the multi-temporal space by Lambin and Strahler (1994a, 1994b) from the multi-spectral vector concept (Malila, 1980; Vigar and Colwell, 1987) is used in the current study as a tool for comparing the two drought indices. The CVA has advantages in the consecutive data analysis and time-series data compression over other change detection methods (such as differencing or principal component analysis) since the two CVA variables, change magnitude and direction, can exclusively be calculated only by this technique. The CVA algorithm was coded onto a graphical modeling script within the ERDAS Imagine image-processing package (ERDAS, 1997).

To compare spatial distributions of the two drought indices, drought-occurred-area (DOA) map was created for every year, and compared to each other. The DOA for each index indicates occurrences and accumulations of droughts during the VGP for every year in relation to the reference year, 18-year median. The DOA of the two indices also was compared to drought-affected-area (DAA) map created from traditional ground-observed weather data. Although traditional method was used as validation for satellite data, the DAA only gives information if there was drought event in a certain year over a certain local level administration, named Soum. Therefore, although ground-observation data does not give knowledge about aerial extension of drought or how larger areas were occurred by drought for certain Soum area, we considered that the whole territory of Soum was affected by drought.

Results and discussion

Temporal and spatial variations of NDVI and LST

Inter-annual variations of NDVI and LST for the three sub-periods of growing season during 18-year in the Desert-Steppe and Desert ecosystems are presented in Figure 2. Along the study period, statistically significant differences of NDVI were exist between the three sub-periods in both the Desert-Steppe (F-stat=73.86, $p<0.0001$) and Desert (F-stat=9.89, $p=0.0002$) ecosystems. However, the NDVI is seasonally varied differently in two ecosystems. In the Desert-Steppe, the lowest NDVI values, about 0.07-0.1, were found at the early part of the VGP and higher values (about 0.12-0.19) were observed at the middle of the VGP (Figure 2a). The NDVI values in the late part of the VGP were located somewhere in-between them (about 0.1-0.16) but closer to the peak value in the season. Overall, the seasonal variation of the NDVI was high in the Desert-Steppe ecosystem than the Desert ecosystem. Contrary, less variation was found between the sub-periods of the season in the Desert ecosystems (Figure 2b). Also, the lowest values of the NDVI (0.04-0.07) were found at the middle of the VGP in the Desert ecosystem in contract to the early season in the Desert-steppe. Besides, the NDVI values in the Desert ecosystem throughout the 18-year period were low, varied from low (0.04-0.08) at the beginning of the growing season to high (0.06-0.1) at the end. The inter-annual variations of LST over the 18-year period shows that the peak of the LST were observed in the middle of the VGP (the hottest summer time) in both the Desert-Steppe (30-39°C) and Desert (35-45°C) ecosystems of Mongolia (Figure 2c and 2d). Clear separations between the sub-periods can be noticed (F-stat=178 for the Desert-Steppe and F-stat=218 for the Desert ecosystem). The lowest LST in both ecosystems were found at the beginning, while the highest at the middle of the VGP. These results suggest that the relations between the variations of NDVI and LST over the growing season can group the study years. The years 1984, 1988, 1990, 1993-94, and 1998, which are characterized by high NDVI and low LST, can be classified as wet years. Contrary, the years with low NDVI and high LST values, such as 1983, 1986, 1989, 1995-96, and 1999, as drought years.

The spatial distribution of the 18-year mean NDVI and LST values in sub-periods of the growing-season over the Desert-Steppe and Desert ecosystems is presented in Figure 3. It can be seen that the NDVI and LST values are typically low at the beginning of growing season or springtime in two ecosystems (Figures 3a and 3d). The reason is the soil moisture is extremely low due to the low amount of rainfall during this time of the area. In addition, strong and enduring winds are common during springtime over the Desert-Steppe and Desert ecosystems when the air is warmed up (Natsagdorj, 2000). However, the higher NDVI values along with lower LST values were found in the northern part of the study area at this time of the season. The NDVI was high during the middle (i.e., summer) and end (i.e., autumn) of the VGP (Figure 3b and 3c) in the Desert-Steppe ecosystem in the northern and central parts of the study area, the Gobi-Altai Mountain and on the fringes of the Depression of Great Lakes, and forward to the south – Desert region. The LST was high in the middle of the season in the south and southwestern regions of the study area, the Gobi Desert, and the rising temperatures were spread to the north to the Desert-Steppe regions throughout the growing season (Figure 3e and 3f). Increase of LST at the beginning of VGP causes increase of NDVI values in the Desert-Steppe and vast areas of the Desert ecosystems. The NDVI variation during the middle of the VGP is not positively supported by the LST increases. Further, downward LST in the late of season aid to the NDVI when reach its peak at the end of the VGP. However, as an increasing of temperature at the beginning of the VGP in the south, plants might be affected by heat and/or water stress during the middle of the VGP (Figure 3b). Under such circumstances, plants cannot re-growth back later in the season, summer and autumn (Figure 3c). The decrease of the NDVI values at the middle and end of the VGP over some southern areas can be explained by increasing of temperature and evaporation over these areas. Hence, high temperature at the middle of the VGP does not support the growth of vegetation in the Desert ecosystem, however increasing temperatures aid to the plant growths in the Desert-Steppe.

Comparison of drought-detection indices derived from the NDVI and LST

Spatial distribution of drought occurred areas (DOA) detected by the two different drought indices derived from the NOAA-AVHRR reflective and thermal datasets over the VGP for three representative years, wet (1993 with 136 mm of annual precipitation), dry (1989 with 44 mm), and normal (1998 with 99 mm), in the Desert and Desert-Steppe ecosystems of Mongolia is shown in Figure 4. Despite the comparison of two indices, those two were evaluated against the traditional drought-affected-area (DAA) maps, except for the normal year 1998 (no data available). It should be noted that the traditional method does not distinguish between sub-periods of the VGP, as can be done with the image derived indices.

Figures 4a and 4b illustrate DOA maps or spatial distribution of droughts that are detected in different sub-periods of the VGP in 1993 (wet year) by the NDVI and LST/NDVI, respectively. Only some areas are detected by two drought-indices in this year. These are identified as droughts at the beginning of the VGP occurring in the same places in the northwest and northern parts of the study area on the DOA maps of NDVI (Figure 4a). However, these areas were not declared as droughts in DAA map by traditional observations (Figure 4c). In this year, relatively larger areas are identified as late (August-September) drought on the DOA maps of LST/NDVI (Figure 4b) while some of them are marked as drought events in the DAA map (Figure 4c). Small areas are identified as beginning and late droughts (e.g., April-May & August-September) by the DOA maps of LST/NDVI over the central and south-west parts of the study area (Figure 4b) whereas the DAA map marks larger areas as drought-affected (Figure 4c) and no droughts are detected by other the NDVI (Figure 4a).

In contrast to the wet year, when precipitation was significantly below normal in 1989, drought events affected large areas as shown by the DOA maps of NDVI (Figure 4d) and LST/NDVI (Figure 4e) as well as the DAA map (Figure 4f). Obviously, both indices detect much larger areas than in the wet year, as shown above. For the dry year, most drought events are identified by the NDVI as combinations of droughts in sub-periods of the VGP (rather than a single period) (Figure 4d). While, the LST/NDVI found several droughts in the middle, end, and entire duration of the VGP (Figure 4e). However, none of the DOA maps of satellite-derived indices matches the DAA map (Figure 4f). In the latter, much larger areas were defined as droughts.

A small area in the northwestern fringe and some eastern and central parts of the study area are identified as droughts at different sub-periods of the VGP in 1998 (normal year) by the DOA maps of NDVI (Figures 4g). However, relatively larger areas in the southern fringe of the study area are identified as drought during the middle and end of the VGP by the LST/NDVI (Figure 4h). Also, small areas are identified entirely as drought during the VGP on the DOA maps of LST/NDVI. Other than a few areas in the east of the study area, spatial distributions of DOA maps of the drought indices do not show similar results in sub-periods of VGP in the normal year.

Summary

Remote sensing indices derived from the reflective and thermal datasets of the NOAA-AVHRR sensor for 18-years from 1982 to 1999 were used to examine the temporal and spatial variations of the NDVI and LST in the Desert-Steppe and Desert ecosystems of Mongolia. Negatively varied NDVI and LST during the VGP in two ecosystems led to the suggestion that the drought events can be predictable more reliable by the combination of these two variables than the use of a single one. Comparison of DOA maps of the two indices shows that they do not show similar results for sub-periods of the VGP. Also, results indicate that there are no agreement in detecting of droughts between the satellite-derived drought-detection indices and the traditional ground-observed drought-affected-areas maps. Wider areas are detected as droughts by ground-observation rather than satellite derived drought-detection indices. Although this can be explained by the different observation methods (ground vs. remote sensing), it can be concluded that ground measurements are less precise over wide regions. This finding should be verified with respect to the indices based on meteorological parameters (e.g., temperature and precipitation).

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========================== **ДОКЛАДЫ** ===================================

РЕЗУЛЬТАТЫ ИСПОЛЬЗОВАНИЯ ПАСТБИЩНОЙ ИНФОРМАЦИИ В ЦЕЛЯХ ПРИНЯТИЯ РЕШЕНИЙ И ОЦЕНКИ ОКРУЖАЮЩЕЙ СРЕДЫ В АФГАНИСТАНЕ

© 2005 г. Джиагво Ки1,2,3, Джон Рэнджит1, Джилалонг Ли4

1 Отдел Географии и Центр исследований глобальных изменений климата и земли, Мичиганский Государственный Университет,
Ист Лензинг, Ml 48823, США
2Университет Ксинжианг, Урумки, Китай
3Университет Джиангкси Нормал, Нончанг, Китай
4Колледж биологических наук, Университет Нанджит, Нанджит, Китай

Пастбища включают большую часть земельных территорий Афганистана, представляя источник кормов для скота и это является основой создания продовольственных ресурсов страны. Более того, около 70% афганского населения живут в сельской местности и зависит от урожайности пастбищ, уровня питания и интенсивности местной перевозки скота. Деградация популяций скота и наблюдающийся упадок продуктивности в течение последних 40 лет засухи, ухудшили состояние пастбищ. Кроме того, межплеменные конфликты продолжающиеся 23 года и международная оккупация, перевели пастбища в категорию угодий, состояние которых зависит от выпадаемых дождей и характера сельскохозяйственного использования. Геополитические конфликты принесли системно экологические изменения в пастбищное использование земель, изменили почвенный покров и систему его использования. Для полной оценки условий Афганских пастбищ и учреждения управления их хрупких экосистем, необходимо выработать реальные, относительно чувствительные пастбищные индикаторы. Поэтому, цель такой постановки - развитие и получение новейших пастбищных информационных данных, включая параметры растительного покрова, высоту травостоя и общую биомассу сообществ, определение их потенциала спутниковой связью.

Вторая цель - выяснить способность и эффективность научного подхода по пастбищной информации - разработанного на юго-западе США, по Афганским аридным и полу- аридным регионам. Результаты включают пространственную распределительную карту пастбищной растительности, включая высоту травостоя, общую кормовую биомассу. Представляемые карты составлены спектральной, не смешивающей моделью, разрабатываемой на юго-западе США. Как пример прилагаются, модельные продукции и схема их использования для изучения деградации пастбищ в 1992-2002 гг.

Для подробного изучения необходимо использовать начальные результаты, установленные для определения пространственного подхода, для разных ландшафтов аридных и полуаридных регионов Афганистана. Впоследствии, информационные показатели пастбищ адаптируются и могут быть успешно использованы для управления продукционными процессами и в оценки деградации земель.

LAND SURFACE PHENOLOGIES OF UZBEKISTAN AND TURKMENISTAN BETWEEN 1982 AND 1999

© 2005. Geoffrey M. Henebry1 , Kirsten M. de Beurs, and Anatoly A. Gitelson

Center for Advanced Land Management Information Technologies (CALMIT),
School of Natural Resources, University of Nebraska-Lincoln,
102 E. Nebraska Hall, Lincoln, NE, 68588-0517 USA
1Corresponding author: ghenebry@calmit.unl.edu; +1-402-472-6158 (-4608 FAX)

INTRODUCTION

Afghanistan lies between 29°35' and 38°40'North Latitude and 60°31' and 75°00' East longitude (Fig. 1). The country is bounded by Iran to the west, the central Asian states of Turkmenistan, Uzbekistan and Tajikistan to the north, China at the eastern most end of the narrow Wakhan corridor, and Pakistan to the south and east (Dupree and Gouttierre, 1997). The principal mountain ranges that run across the country in a northeast-southwest axis are the Hindu Kush system and its subsidiary ranges of Suleiman, Koh-e Baba, Salang, and Safid Koh; this collection of systems and ranges topographically divide the country into the Central Highlands (includes Hindu Kush and its subsidiary ranges), the Northern Plains, and the Southwest Plateau (Thieme and Suttie, 2000). The snowline generally varies between 3600-4000 meters in summer and averages 1800 meters in winter (Thieme and Suttie, 2000).

Afghanistan's land area is approximately 652,290 square kilometers, and a significant portion (45.2 %) of its landmass is covered by rangelands (FAO/UNDP, 1999), which are an important source of forage for livestock (ICARDA, 2002). A large percentage of the population is rural (70%) and depends on livestock for diet and transportation (ICARDA, 2002). The livestock population is in decline due to a number of factors, the most important of which is three consecutive years of drought that eased in 2002 (Lautze et al., 2002). The Soviet occupation of Afghanistan lasted a decade (1979-1989), and was followed by a decade of civil war, and finally by the current American occupation. The ongoing foreign occupations and civil wars have caused large segments of the population to lose their livelihoods (ICARDA, 2002). The natural environment was additionally affected due to the large number of land mines sown during the years of conflict (Ali and Mc Cauley, 2002) as they prevented access to productive land and forced herders to take their flocks to marginal, overgrazed lands. During recent years, rangelands were converted to both irrigated and rain fed agriculture (FAO/WFP, 2003). Furthermore, during the past decade, the remaining forest cover (presently 2%) was severally depleted by widespread deforestation, which in turn lead to widespread erosion and degradation of surrounding rangelands through the loss of topsoil (Ali and Mc Cauley, 2002). Afghanistan, similar to most semi-arid regions of South Asia, is dependent on very sparse and seasonal precipitation in the form of rainfall and snow (ICARDA, 2002). Such precipitation patterns cause spatio-temporal variations in the distribution of rangelands. Elevation is another factor in variability of rangeland distribution as the country is mountainous and the elevation ranges from 300 to ~7500 meters. In addition to altitudinal cline, the pastoral lifestyle of the Kuchi nomads and their practice of Transhumance result in grazing of low elevation pastures during the winter and high altitude pastures during the summer (ICARDA, 2002). Satellite remote sensing allows more robust assessment of such complex human-environment systems and is an effective tool to facilitate better management of rangeland resources. Therefore, the objective of this study is to develop and generate up-to-date rangeland information products (green and senescent fractional cover, forage height, and forage biomass) and address important tempo-spatial forage distribution factors.

Effective grazing management can result in livestock-centered and potentially significant economic growth in Afghanistan. Prior to 1979, Afghanistan was essentially self-sufficient in food production and was a major exporter of dried fruits, nuts and livestock products, especially textiles and hides. However, more than two decades of successive and ongoing conflicts, and the resulting drought and economic and human disruption from these conditions led to large-scale deterioration of the agricultural production base and to rampant decay of Afghanistan's physical infrastructure. . The agriculture sector also witnessed the exodus of technical and managerial staff and support during the past 30 years. For example, Registan, a desert region previously home to more than 250,000 nomadic and settled Kuchi herders and their families, suffered greatly from overgrazing and from the severe drought in the late 1990s and early 2000s. As a consequence of the resultant environmental degradation, the Kuchi settlements within Registan have been largely abandoned. This example illustrates the need to provide Afghanistan with decision-making and assessment tools for rangeland conditions to allow them to rehabilitate, monitor, and manage their pastures. The objective of this paper is to demonstrate the ability to use remote sensing imagery to map rangeland information products for Afghanistan using coarse resolution satellite images from the Moderate Resolution Imaging Spectrometer (MODIS) on board the Terra and Aqua satellites.

MATERIALS AND METHODS

Data Set Description

For the entire country of Afghanistan, MODIS derived 16-day composite vegetation indices at 250-meter spatial resolution were acquired from NASA's EOS (Earth Observing System) data gateway for the growing season of 2002 (June-October). We chose the enhanced vegetation Index (EVI) product because of its sensitivity in detection of high biomass, and its additional benefits such as reduced atmospheric influences as well as detection of canopy background signal through decoupling (Huete et al., 2001). MODIS derived 8-day composite surface reflectance images at 500-meter spatial resolution were also acquired for the same extent and duration as above. This reflectance dataset consists of seven MODIS bands corrected for the effects of atmospheric gases, cirrus clouds and aerosols (Vermote and Vermeulen., 1999). Bands 2 (Red) and 6(Short wave infrared (SWIR)) were selected to compute the normalized difference senescent vegetation index (NDSVI). NDSVI is a recently-developed index for successfully mapping senescent vegetation (Qi et al., 2002) in arid and semi-arid environments. This index is based on data collected from Southeast Arizona and the resultant analysis indicates high accuracy in detection of senescent vegetation biomass (Qi et al., 2002) in this semi-arid region of the United States.

To validate our MODIS-based rangeland information products for the 2002 growing season, several images of Afghanistan's northern regions were acquired from Landsat 7's ETM+ sensor for the same time period. The ETM+ imagery was first radiometrically corrected for at-sensor reflectance using the calibration parameters in the metadata and then to surface reflectance after correcting for atmospheric effects using the MODTRAN-4 code. The MODIS vegetation indices and surface reflectance data were re-projected from their native integerized sinusoidal (ISIN) projection to geographic (LAT/LONG) projection using the MODIS re-projection tool and re-sampled using the nearest neighbor method.

Rangeland Information Products from Remote Sensing

Remotely sensed data have demonstrated the ability to provide rangeland information at various spatial and temporal scales (Tueller, 1989, Ridd, 1995 and Wylie et al., 1995). Most of these applications focused on spectral indices such as the normalized difference vegetation index (NDVI) for the linkage of rangeland vegetation dynamics with remotely sensed data (Hostert et al., 2003, Leprieur et al., 2000 and Moleele et al., 2001). However, the operational use of NDVI in rangeland management is limited partly because NDVI is not an accurate total biomass indicator. NDVI is a measure of green vegetation and therefore is not very useful in arid and semi-arid landscapes where senescent forage is abundant in fall and winter (Qi et al., 2002). Therefore, in order to provide reliable estimates of senescent and green biomass estimates, usage of a senescent vegetation index as well as an advanced vegetation index such as EVI is justified.

The frequent acquisition cycle and large footprint of moderate-resolution sensors such as MODIS are particularly well suited for monitoring the spatio- temporal dynamics of rangelands of a large country such as Afghanistan.

The first product is the fractional cover of rangeland grasses. Fractional cover is the most critical parameter for range management decisions because it measures surface percentage of total vegetation cover. Fractional cover for green vegetation was demonstrated feasible (Qi et al., 2002) using a simple linear unmixing model and spectral vegetation indices. Previous studies (Gutman and Ignatov, 1998 and Zeng et al., 2000) involving linear mixing utilized NDVI to estimate fractional green cover, but in this study NDVI was replaced with EVI from MODIS images.

$$EVI = G \times \frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + c_1 \times \rho_{Red} - c_2 \times \rho_{Blue} + L} \quad (1)$$

where ρ_{NIR}, ρ_{Red} and ρ_{Blue} are the atmospherically corrected surface reflectances for near infrared (NIR), red, and blue bands, respectively, L is the canopy background brightness correction factor, c_1 and c_2 are the atmospheric resistance coefficients for red and blue bands, respectively, and G is the gain factor. The coefficient constants of the EVI equation (Huete et al., 2001) were $L = 1$, $c_1 = 6$, $c_2 = 7.5$, and $G = 2.5$.

In the arid and semi-arid environments of Afghanistan, rangeland grasses are often senescent. Because livestock benefit from these dried grasses in the region, a remotely-sensed senescent biomass indicator is the second product developed for our geospatial rangeland toolkit. The ETM+ detector uses two SWIR spectral bands (5 and 7) near the water absorption region of the electromagnetic spectrum that can infer signals from senesced vegetation (Qi et al., 2002). The spectral response in these bands (especially band 5) increases as the vegetation senesces due to loss of water in leaf tissue (Tucker, 1980). The senescent vegetation index or NDSVI (Qi et al., 2002) is derived using the equation:

$$\text{NDSVI} = (\rho_{\text{swir}} - \rho_{\text{red}}) / (\rho_{\text{swir}} + \rho_{\text{red}}) \tag{2}$$

where ρ_{swir} and ρ_{red} are atmospherically corrected surface reflectance in SWIR and red bands, respectively. Similar spectral bands on MODIS, namely, Band 2 (841-876 nanometers) and Band 6 (1628-1652 nanometers) can be used in this equation to calculate the senescent vegetation indices at 500-meter spatial resolution.

Although green and senescent vegetation fractional cover maps are important rangeland products, the ultimate decision on grazing capacity is most likely related to total fractional vegetative cover, an important biophysical attribute (Foody et al., 1997, Skole and Qi, 2000). Total fractional vegetative cover is not only an indicator of biomass, but also an important surface variable that controls hydrological processes in arid and semi-arid regions (Shuttleworth, 1995, Goodrich et al., 2000). The fractional cover (either green or senescent or total cover) can be derived from the following equations (Gutman and Ignatov, 1998, Zeng et al., 2000, Qi et al., 2000, Maas 1998):

$$fc = \frac{VI - VIs}{VIg - VIs} \tag{3}$$

Where VI is a vegetation index (can be NDVI, NDSVI, or EVI), and VIg and VIs represents two endmembers of full canopy closure of grass and bare soils, respectively.

Canopy height is a product developed for calculating rangeland total forage. Canopy height is more advantageous than fractional cover because fractional cover only describes the horizontal density of vegetation and therefore is less indicative of the total biomass (Qi et al., 2002). Previous studies (Qi et al., 2002) found that forage height (H) was highly correlated with NIR reflectance and can be expressed as the following:

$$H = \alpha(c - \rho_{NIR}) + \beta \tag{4}$$

where α and β are regression coefficients and c is a constant. The coefficients and constant were determined from previous studies using data from arid and semi-arid regions of southeast Arizona (Qi et al., 2002).

Another important rangeland information product is total forage. As its name implies, total forage is a measurement of total available food for livestock. Total forage is highly correlates with forage volume and can be derived from the product of fractional cover and canopy height. The total amount of forage, F, is then:

$$F = v_1(H \times fc) + v_2 \tag{5}$$

where v_1 and v_2 are regression coefficients derived by empirically fitting the forage variable to the product of canopy height and fractional cover. Other studies of rangeland productivity (Volk, 1972, McArthur et al., 1979, Casimir et al., 1980, Thieme and Suttie, 2000) found that the average production of forage biomass varied between 0.41 to 5 tons per ha. As no measurements were available from Afghanistan, we used the published results from literature to obtain the upper and lower limits of biomass with an average of 1205 kg/ha (approx). To improve rangeland information products, these equations can be better calibrated by applying actual field data measurements (rather than estimates) to the algorithm before processing of satellite images.

RESULTS AND DISCUSSION

Spatial Distributions of Rangeland Information

The two sets of images (250-meter and 500-meter) acquired with MODIS sensors and composited from August 29 to September 13, 2002 were used in the equations discussed above to estimate total fractional vegetative cover, forage height, and total forage over the entire region encompassing Afghanistan. The total fractional rangeland grass cover (Fig. 2) showed that most parts of the country had low coverage since the time series corresponds with the dry season. When forage height is examined (Fig.3), taller grasses are indicated in the central region of Afghanistan with significant difference in their spatial distribution. Although fractional cover may not be high during this time of year, height varies substantially from location to location and is indicative of potential differences in grass species, soils, and topography. Examination of the digital elevation data (DEM) revealed that taller grasses are distributed in lower elevations due to water accumulations. Although similar in pattern to forage height, total forage biomass (kg/ha) was much lower than expected across the entire country (Fig. 4). The maximum forage amount was around only 1000 kg/ha. However, interpreters should be mindful of inherent spatial variability of these products inherent spatial variability. Although the highest value can be 1000kg/ha, for example, only one pixel or a very small set of pixels can contain such high values.

Validation and Verification of Rangeland Products

As stated earlier, it was not possible to acquire intensive field data to conduct a complete validation for these products. However, an indirect method was used for calibration and validation. A two-week trip to Afghanistan during summer of 2003 was made to collect forage height, fractional cover, and total forage. Coordinates from a GPS were recorded at 125 sites (Fig. 5) across the country from June 16 to June 30. Due to customs and safety problems encountered with bringing sophisticated field spectrometers such LI-Cor LAI 2000 into the country, digital photographs were taken to determine grass type, fractional cover, and forage height. After examining surveys and photographs, the main natural vegetation type for grazing was determined to be the *Artemisia* steppe community along with *Poa* spp, *Alhagi* spp, and *Stipa* spp (McArthur et al., 1979; Thieme and Suttie, 2000); all range in height from 15 to 25 cm (ground measurements). The field survey data were used in the previous equations to compute the fractional cover, forage height, and total forage biomass.

Field surveys were used to calibrate the rangeland products using ETM+ images (30-meter spatial resolution) precisely georeferenced to the 125 surface GPS points. The products derived from MODIS images were then compared with those derived from ETM+ images. The correlation coefficients for green fractional cover, senescent fractional cover, forage height, and total forage (green biomass and senescent biomass) between the two sensors were 0.94, 0.93, 0.87, and 0.96, respectively. The statistical measures of goodness of fit, R^2, were 0.89, 0.86, 0.76, and 0.97, respectively. Figure 6 is a plot showing the correlation between biomass estimates from the two sensors. These findings suggest that rangeland products derived from ETM+ imagery can be aggregated from local to regional scales by utilizing MODIS derived products. In order to further validate our products, an extensive literature review was conducted to search for any previously reported values of forage biomass in Afghanistan. The results are listed in Table 1 for comparison purposes. The findings strongly indicate that our indicator values were in the same range as most of the reported values. Therefore, all rangeland information products derived from MODIS data are believed to be fairly accurate and useful for daily management, assessment, and rehabilitation of rangelands.

An Example Application

Spatial distributions of forage production can be important tools for managers to assess rangeland conditions and productivity. For example, multi-temporal products can be used to assess rangeland degradation. To demonstrate this application, sensor imagery acquired in 1992 by AVHRR (Advanced Very High Resolution Radiometer) and in 2002 by MODIS were used to derive total fractional green vegetation cover (because AVHRR sensor does not contain a SWIR detector, products other than total fractional green vegetation cover were not derived). The 1992 imagery represents the rangeland condition prior to Taliban regime while the 2002 imagery is post-Taliban. The mean fractional cover values of the peak growing season in southeastern Afghanistan (November – February) were averaged to represent the maximal growth (Fig.7). As can be seen, majority of Afghanistan's rangelands had less than 30 percent vegetative cover for both 1992 and 2002. The 10 percent increase in bare lands (0-10 percent binned cover) from 1992 to 2002 is most likely due to changes in land management policies after 1996 and the decades-long severe drought.

The 10 percent increase in barren lands was at the cost of forage in the 20 percent and 30 percent rangeland cover bins. These reductions were 7 percent and 4 percent, respectively. Although these percentages do not seem to be large, they may be threshold values that can aid in determining whether fragile ecosystems such as arid and semi-arid environments can recover from sustained human and natural disturbances. Figure 7 also indicates a substantial reduction in rangeland productivity between 1992 and 2002. Decline of forage productivity may be a harbinger of significant economic and environmental consequences for this region as vast majority of the population relies heavily on livestock for its major source of sustenance.

CONCLUSIONS

Rangeland productivity algorithms, developed for arid and semi-arid Southwest USA, could be applied in Afghanistan to derive a suite of rangeland information products. The techniques developed using high spatial resolution of Landsat images could also be applied to larger regional studies using medium to coarse spatial resolution MODIS images with similar high accuracies in results. These rangeland information products not only provide answers to common range management inquiries but also can quantitatively assess local and regional rangeland degradation by utilizing multi-temporal satellite images.

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========================== ДОКЛАДЫ ==================================

ВЛИЯНИЕ ВОДНОГО ФАКТОРА НА СТРУКТУРУ И ФУНКЦИОНИРОВАНИЕ ГИДРОФИЛЬНЫХ ОРНИТОКОМПЛЕКСОВ АЙДАРО - АРНАСАЙСКИХ РАЗЛИВОВ

© 2005 г. С.Э.Фундукчиев
Самаркандский государственный университет
703008 Самарканд, ул. Ката-Курганская 1, Узбекистан

Проблеме птицы в антропогенном ландшафте - у нас и за рубежом уделяется большое внимание. В течение последних трех десятилетий эта проблема находится в центре внимания специалистов, довольно бурно обсуждается на всякого рода конференциях. Средняя Азия, в частности Узбекистан могут служить классическим объектом в изучении закономерностей формирования населения птиц антропогенных ландшафтов, особенностей их биологии. Этому способствует географическое положение республики, ее природные условия , интенсивность трансформации пустынных территорий под влиянием хозяйственной деятельности человека.

Возникающие водоемы (в результате хозяйственной деятельности в аридной зоне) быстро осваиваются различными животными и прежде всего птицами, как наиболее мабильными позвоночными. В пустынной зоне это может привести к существенным изменениям путей кочевок и пролета птица, прежде всего водно-болотных, а также к изменениям в фауне гнездящихся и зимующих птиц. поэтому важно знать особенности формирования и динамику орнитофауны на таких водоемах, степень пригодности их для обитания птиц в период миграций, гнездования, линьки и зимовки, возможность практического использования водоемов такого типа в деле охраны ценных и хозяйственно значимых групп.

Материал и методы. В основу статьи положены как литературные, так и собственные данные собранные в течение 1992 - 2001 гг., на Айдаро - Арнасайской системе озер, Денгизкуль и др. Исследования проводились во все сезоны года, что потребовало применения нескольких взаимодополняющих методик. Птицы учитывались аэровизуально (Исаков, 1952; Зыкова и др., 1965) и во время пешеходных исследований.

Результаты и обсуждение. В настоящее время площадь орошаемых земель в Узбекистане равна 3,7 млн.га. За последние десятилетия в республике построено 33 искусственных водохранилищ, 35 крупных каналов. Созданы сеть коллекторов и дренажей в Голодной, Джизакской, Каршинской, Язъяванской, Карнабчульской степях и в низовьях Амударьи.

В результате освоения и сбора промывных вод образовано несколько крупных и мелких водоемов.

С выведением на поверхность подземных (артезианских) вод, возникли мелкие озера в пустынных районах. В республике функционирует более 30 рыбных комбинатов и рыбопрудовых хозяйств. Около 35 озер используются в рыбохозяйственных целях. Из этого многообразия водоемов особый интерес представляют сбросные и в частности Айдаро-Арнасайские разливы.

Эта система озер один из самых северных и крупных сбросных водоемов Средней Азии (площадь водной поверхности 2320 м2). Он образовался на месте солончака Айдар и соленого озера Тузкан в результате сброса в Арнасайскую впадину воды после зимней промывки полей в 1956 г и сбросов излишков воды из Чардарьинского водохранилища (2 млрд.м3) в многоводные 1968 -1969 гг. (Решетников, 1956). За эти годы в пустыне возник необычный природный комплекс: обширные озера с изрезанными берегами, множеством островов, тугайными зарослями вдоль побережья

В настоящее время Арнасайская впадина представляет собой ряд озер (удлиненных и округлых по форме), в которых около 18 куб.км. воды. И лишь в северной части , там где

Арнасай переходит в долину Сырдарьи, она не изменила своего прежнего вида. По южному берегу тянутся тугайные заросли шириной 50-100 м. К тугаям прилегает полоса степи, через 1,5-2 км к югу от озера начинаются предгорья Нуратинского хребта. Вся система озер взаимосвязана проливами шириной от 2-5 до нескольких десятков метров. Глубина их составляет в среднем 2-5 м, дно плоское и очень топкое. В прибрежной части разливов имеется много мелководий глубиной 0,5-1,0 м. Большинство озер обросли густой стеной тростника (Phragmites Adans), рогоза (Typha L.). В отдельных местах они настолько густы, что человеку трудно пробираться. В центральной части озер широко распространены уруть (Myriophyllum L.) и гребенчатый рдест (Potamogeton pectinatus). Берега их густо заросли солянками (Salsola L.), ажреком (). Обширность водной площади и обилие кормов привлекают на Арнасайские разливы массу околоводных и водных птиц, как в период пролета и зимовок, так и на гнездование.

В зимние периоды в связи с континентальностью климата на северо-западе республики возможны резкие снижения температур, при этом в Арнасайской котловине температура иногда снижается до -300. В силу этого на водоемах Узбекистана, в частности и на Арнасайских разливах, длительные и стабильные зимовочные скопления птиц, такие как, например, на юге Каспия, не образуются. Поэтому в такие зимы, многие виды откочевывают южнее. В благоприятные же годы здесь собирается большое количество птиц. наиболее многочисленны - лысуха (Fulica atra), чирок-свистунок (Anas crecca) и кряква (Anas platyrhynchos) (наблюдаются скопления птиц с числом птиц более 1000); обыкновенны - серый гусь (Anser anser), серая утка (Anas strepera), красноносый (Netta rufina) и красноголовый (Aythya ferina) нырки, луток (Mergus albellus), серая цапля (Ardea cinerea) (отмечены скопления с числом птиц более 100); малочисленны и редки - свиязь (Anas penelope), шилохвость (Anas acuta), пеганка (Tadorna tadorna), гоголь (Bucephala clangula), большой крохаль (Mergus merganser).

В период весенних и осенних пролетов эти разливы характеризуются большим разнообразием видов и численностью водоплавающих и околоводных птиц - веслоногих (Pelecaniformes), голенастых (Ciconiformes), гусеобразных (Anseriformes), ржанкообразных (Charadriiformes) (особенно много уток и куликов). Нами отмечено 16 видов гусеобразных (Anseriformes) и 18 видов ржанкообразных (Charadriiformes) птиц.

Большое число небольших озер густо заросших тростниковой растительностью, а также наличие многочисленных островов, привлекают птиц в период размножения. Озеро Тузкан - одно из наиболее южных мест гнездования большого баклана (Phalacrocorax carbo). В тростниковых зарослях устраивают свои гнезда большая поганка (Podiceps cristatus), серая цапля (Ardea cinerea), волчок (Ixobrychus minutus), лысуха (Fulica atra), камышница (Gallinula chloropus) и другие. На небольших островах и по берегам в траве гнездятся белохвостая пигалица (Chettusia leucura), ходулочник (Himantopus himantopus), луговая тиркушка (Glareola pratincola), чайконосая (Gelochelidon nilotica), речная (Sterna hirundo) и малая (Sterna albifrons) крачки и другие птицы. Всего 59 гнездящихся птиц (таблица).

Большое значение для гнездования наземногнездящихся видов на озерах Айдаро-Арнасайской системы имеет сочетание таких условий, как глубина водоема, степень его зарастания гидрофитами и наличие невысоких пологих островов, сложенных легкими песчаными отложениями. На окруженных широким тростниковым поясом мелководных плесах даже при наличии постоянного ветра острова довольно устойчивы к действию небольших волн. На больших глубоких местах разливов, со слабо развитой надводной и подводной растительностью скорость переработки островов и берега довольна высока, тогда как именно здесь предпочитают гнездиться кудрявый (Pelecanus crispus) и розовый (Pelecanus onocrotalus) пеликаны, чегравы (Hydroprogne tschegrava), чайконосые крачки (Gelochelidon nilotica), морские голубки (Larus genei). Сильные ветровые явления ведут к разрушению гнездовых построек. При умеренных и слабых ветровых воздействиях некоторые наземногнездящиеся виды могут активно надстраивать гнезда так же, как и при подъеме уровня воды.

Формирование гидрофильных орнитокомплексов и их динамики протекают не отдельно, а в тесной связи с сукцессионными процессами, идущими в водных экосистемах, накладываются на них и это наложение создает своеобразный отпечаток на структуре птичьего населения.

Сравнительно быстрое заселение мелководных разливов естественного происхождения личинками разнообразных насекомых, причем в значительном количестве, создает прекрасную кормовую базу для многочисленных мелких бенто- и энтомоядных видов - различных камышовок (Acrocephalus), куликов (Charadriidae). Последующее развитие водных экосистем связано с появлением макрофитов, повышением разнообразия беспозвоночных животных, заселением водоемов ихтиофауной и усложнением ценотических связей.

Таблица.Видовой состав птиц сбросовых водоемов

	Виды птиц	Айдаро-Азнасайские разливы	озеро Денгиз-куль	Экологичес кие группы	Характер пребывания
1	2	3	4	5	6
I	**Podicipediformes**				
1	Podiceps cristatus	+	+	V	n
2	Podiceps ruficollis	-	+	V	n
II	**Pelecaniformes**				
3	Pelecanus onocrotalus	+	+	V	m
4	Pelecanus crispus	-	+	V	m
5	Phalacrocorax carbo	+	+	V	n
6	Phalacrocorax filamentosus	+	+	V	n
	Ciconiformes				
7	Ardea cinerea	+	+	V	n
8	Ardea purpurea	-	+	V	n
9	Egretta alba	+	+	V	w
10	Nycticorax nycticorax	+	+	V	n
11	Ixobrychus minutus	+	+	V	n
12	Botaurus stellaris	+	+	V	w
13	Platalea leucorodia	+	+	V	n
	Anseriformes				
14	Anser anser	+	+	V	n
15	Tadorna ferruginea	+	+	V	n
16	Tadorna tadorna	+	+	V	n
17	Anas platyrhynchos	+	+	V	n
18	Anas crecca	+	+	V	m
19	Anas strepera	+	+	V	m
20	Anas clypeata	+	+	V	m
21	Anas penelope	+	+	V	w
22	Anas acuta	+	+	V	w
23	Anas querquedula	+	+	V	m
24	Netta rufina	+	+	V	m
25	Aythya ferina	+	+	V	m
26	Aythya fuligula	+	+	V	w
27	Bucephala clangula	+	+	V	w
28	Mergus albellus	+	+	V	w
29	Mergus meranser	-	+	V	w
	Falconiformes				
30	Pandion halieetus	-	+	V	m
1	2	3	4	5	6
31	Neophron percnopterus	+	+	O	m
32	Circus aeruginosus	+	+	V	m
33	Falco subbuteo	+	-	D	n
34	Falco tinnunculus	+	+	D	n
	Gruiformes				
35	Grus grus	+	+	L	m
36	Anthropoides virgo	+	+	L	m

	Ralliformes				
37	Fulica atra	+	+	V	n
38	Gallinula chloropus	+	+	V	n
39	Rallus aquaticus	+	+	V	n
	Otidiformes				
40	Otus undulata	+	+	L	n
	Charadriiformes				
41	Burhinus oedicnemus	+	+	L	n
42	Charadrius dubius	+	+	V	m
43	Charadrius alexandrinus	+	+	V	m
44	Vanellus vanellus	+	+	V	m
45	Chettusia leucura	+	+	V	n
46	Himantopus himantopus	+	+	V	n
47	Recurvirostra avosetta	+	+	V	m
48	Tringa ochropus	+	+	V	m
49	Tringa glareola	+	+	V	m
50	Tringa totanus	+	+	V	m
51	Tringa erythropus	+	+	V	m
52	Tringa hypoleucos	+	+	V	m
53	Philomachus pugnax	+	+	V	m
54	Phalaropus lobatus	+	+	V	m
55	Calidris minuta	+	+	V	m
56	Calidris alpina	+	+	V	m
57	Gallinago gallinago	+	+	V	m
58	Glareola pratincola	+	+	V	n
	Lariformes				
59	Larus argentatus	+	+	V	n
60	Larus genei	+	+	V	n
61	Larus ridibundus	+	+	V	n
62	Gelochelidon nilotica	+	-	V	n
63	Chlidonias hibrida	-	+	V	n
64	Sterna hirundo	+	+	V	n
65	Sterna albifrons	+	+	V	n
1	2	3	4	5	6
	Colubiformes				
67	Columba livia	+	+	N	n
68	Streptopelia turtur	+	+	D	n
	Pterocletiformes				
69	Pterocles orientalis	+	+	L	n
	Cuculiformes				
70	Cuculus canorus	+	+	D	n
	Strigiformes				
71	Bubo bubo	+	+	O	n
72	Athene noctua	+	+	O	n
	Caprimulgiformes				
73	Caprimulgus aegyptius	+	+	L	n
	Coraciformes				
74	Merops apiaster	+	+	O	n
75	Merops superciliosus	+	+	O	n
76	Coracias garrulus	+	+	O	n
77	Upupa epops	+	+	D	n
	Apodiformes				
78	Apus apus	+	+	N	m
	Passeriformes				
79	Galerida cristata	+	+	L	n
80	Alauda gulgula	+	+	L	n
81	Calandrella cinerea	+	+	L	m

82	Melanocorypha calandra	+	-	L	n
83	Riparia riparia	+	+	O	n
84	Hirundo rustica	+	+	N	n
85	Oriolus oriolus	+	-	D	n
86	Pica pica	+	+	D	n
87	Corvus ruficollis	+	+	D	n
88	Corvus corone	+	-	D	n
89	Corvus cornix	+	-	D	w
90	Corvus frugilegus	+	+	D	m
91	Coloeus monedula	+	+	O	n
92	Parus bocharensis	+	+	D	n
93	Panurus biarnicus	+	+	V	w
94	Muscicapa striata	+	+	D	m
95	Saxicola torquata	+	+	L	m
96	Oenanthe hispanica	+	+	O	n
97	Oenanthe deserti	+	+	L	n
98	Luscinia svecica	+	-	L	m
99	Luscinia megarhynchos	+	-	D	m
1	2	3	4	5	6
101	Acrocephalos arundinaceus	+	+	V	n
102	Hippolais caligata	+	+	L	n
103	Silvia nana	+	+	D	n
104	Scotocerca inquita	+	+	D	n
105	Agrobates galactotes	+	+	D	n
106	Motacilla alba	+	+	D	n
107	Motacila citreola	+	+	V	n
108	Anthus richardi	+	+	L	m
109	Lanius minor	+	+	D	m
110	Lanius schach	+	+	D	n
111	Lanius isabellinus	+	+	D	m
112	Acridoteres tristis	+	+	O	n
112	Emberiza leucocephalos	+	+	V	m
113	Emberiza bruniceps	+	-	L	n
114	Emberiza schoeniclus	+	+	V	m
115	Passer montanus	+	+	N	n
116	Passer indicus	+	+	D	n

Примечание: выше использованы следующие условные обозначения по экологическим группам (1) и характеру пребывания (2). 1.V- водно-болотный; L- луго-полевой; D- древесно-кустарниковый; N- населенные пункты; O- обрывы и горы. 2. r- оседлый; n- гнездящийся; m- пролетный; w- зимующий.

Этот этап сопровождается увеличением видового разнообразия в сообществах куликов и использованием новых кормовых объектов мелкими фитофагами (утиными) и ихтиофагами (поганковыми, чайковыми).

Дальнейшее развитие сукцессионных процессов обусловлено существованием экосистем водоемов в течение нескольких сезонов (что возможно лишь при наличии регулярного питания) и зарастанием этих водоемов высшей водной растительностью, которая образует так называемые тростниково-рогозовые плавни. При этом ценность такого биотопа для птиц заключается в его высоких кормовых и защитных свойствах. Эта стадия характеризуется заселением или, по крайней мере, присутствием крупных фитофагов (серый гусь - Anser anser) и ихтиофагов (голенастых - Ciconiformes, веслоногих - Pelecaniformes). Такова общая схема формирования гидрофильных орнитокомплексов.

Таким образом Арнасайские разливы служат местом крупного скопления птиц на протяжении всего года. Это особенно важно в связи с прогрессивными изменениями:

высыханием Аральского моря и дельты Амударьи, и появлением сравнительно большого количества водоемов искусственного происхождения, а это в свою очередь, изменило распределение сообществ птиц.

Район Айдаро-Арнасайской системы озер, как и другие такого рода водоемы, представляют большую ценность и с хозяйственной точки зрения. Это крупные рыбохозяйственные водоемы, условия которых благоприятны для обитания многих промысловых видов рыб. Богатство авифауны делают эти озера одними из лучших в Узбекистане охотугодий.

К сожалению, в настоящее время, этот уникальный уголок природы находится в критическом состоянии, так как разливы постоянно посещаются рыбаками, сильно развито браконьерство. Одним из наиболее губительных факторов для птиц, обитающих на этих озерах - периодические колебания воды в озере. В результате чего оказываются затопленными места гнездования многих видов птиц. Детальное изучение Айдаро-Арнасайской системы озер и создание здесь системы охраняемых природных территорий необходимо с точки зрения рационального природопользования и, безусловно сыграет положительную роль, как в деле охраны природы так и в развитии народного хозяйства республики.

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THE INFLUENCE OF AQUATIC FACTOR ON STRUCTURE AND FUNCTIONAL ASPECTS OF HYDROPYLE ORNITOCOMPLEXES OF AYDAR-ARNASAY REGION OF CENTRAL ASIA

© 2005. S.E. Fundukchiev

Samarkand State University
703008, Samarkand, Katta-Kurganskaya 1, Uzbekistan

Central Asia is well known by its fauna richness. Of the 15,000 species of wild animals, the vertebrates are represented by five classes including 666 different species: birds (424), mammals (97), fish (83), reptiles (53) and amphibians (2).

Some 53 of these species are endemic.

Reptiles include lizards (toad agama, monitor lizard, gecko) and snakes (viper, gourza, Central Asian cobra). Of the large mammals, goitered gazelle and sigak are particularly worthy of protection. Jackals, wild boar, honey badger, wolves, foxes, porcupines, badgers and hedgehogs dwell in the plains and foothill areas. The rich diversity of bird life includes eagles, jackdaws and kites.

The region faces a serious challenge to its fauna and natural resource base in general.

Intensive anthropogenic activity cause to wide scale transformation of natural landscape in Central Asia. The recent changes in climate and factors affecting land use decision and the region has led to changes in cropland abandonment, destocking of certain rangelands and increased stocking of others, degradation of soils due to salinisation and desertification, and damage to wetlands due to modifications of water regime.

Artificial water pools burn by human activity in arid regions for irrigation of different field crops are quickly colonized by different wild animals, and first of all by birds as more mobile species of vertebrate animals. The formation of hydrophyl ornitocomplexes and their dynamics took place not separately, but in close link with succession processes going on total intire ecosystem. At the same way it leads to formation of unique structure of bird's population.

Comparatively fast colonization of small water pools by different forms of insects creates favorable fodder base for huge amount of migrating birds (Acrocephalus, Charadriidae).

. .Further development of aquatic ecosystem linked with appirience of macrophytes, diverse forms of invertebrate animals, colonization by ihtiofauna and complex cenotic relationships between these forms. Species richness and utilization of new fodder resources characterize this period by small phytophags (Auserifomes, Lariformes, Podicepediformes). During further several years it takes place colonization of this pools by representatives of vascular plants as valuable fodder reserve.

This may cause in the future, to significant changes of migration traffics, nesting behavior and fauna of over-wintering birds at all.

Therefore, it is very important to know peculiarities of formation and dynamics of ornithofauna at these aquatic ecosystems, their suitability for colonization by birds in a different season of the year, and applicability of this ecosystem in practical preservation of endangered species.

========================= **ДОКЛАДЫ** ===================================

АРИДНОЕ ПОЧВООБРАЗОВАНИЕ И ПРОБЛЕМЫ ЕГО ИЗУЧЕНИЯ В РЕГИОНАХ ЕВРОПЕЙСКОГО ЮГА РОССИИ

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Прикаспийский институт биологических ресурсов
Дагестанского научного центра РАН
367025, г. Махачкала, ул. Гаджиева 45, Россия

Изучение процессов аридного почвообразования проводится в Прикаспийском институте биологических ресурсов ДНЦ РАН в пределах регионов Европейского юга России. Исследовательская работа сосредоточена на территории равнинного Дагестана, поскольку самая южная и типичная пустынно-степная климатическая обстановка, как основной фактор почвообразования, проявляется на территории Дагестана. При определении процессного уровня дифференциация стадий опустынивания мы руководствуемся принципами признания определенного типа отношений между взаимосвязанными компонентами наземных экосистем при которых изменение одного компонента приводит к смене другого, как правило способствуя развитию процессов деградации. Из комплекса факторов – почвообразователей наибольшее влияние на почвы оказывают климатические условия и растительность. Не отрицая значимости зоологических, гидрологических, биохимических критериев мы считаем, что приоритетом в определении стадий процессного уровня должны стать почвенные и климатические характеристики. Руководствуясь этими предпосылками на данном этапе исследований целесообразно принять за основу динамику почвообразования и их зависимость от параметров почвенного климата. Установленные параметры почвенного климата изменяются в зависимости от способов воздействия на растительный покров, определяемый плотностью выпасаемого поголовья скота. Процессы перегрева поверхности почвы под влиянием солнечной радиации проникая внутрь почвенной массы оказывают существенное влияние на преобразование органической и минеральной части почв. Можно полагать, что установленный для сероземов Центральной Азии процесс преобразования илистых частиц в профиле является характерной чертой опустынивания. Познание этих закономерностей даст возможность для оптимизации температурного режима почв, способствующего повышению продуктивности природных кормовых угодий и улучшению продовольственной базы населения.

ARID SOIL FORMATION AND THE PROBLEMS OF ITS STUDYING IN THE SOUTH REGIONS OF RUSSIA

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Caspian Institute of biological resources, Daghestan scientific center,
Russian Academy of sciences.
367025, Makhachkala, M. Gadjiev 45, Russia

Study of arid soil formation is undertaken in Caspian Institute of biological resources DSC RAS, including South regions of Russia. The major part of our research on this problem is concentrated on the territory of Caspian plain in Daghestan republic, where the most typical desert-steppe climatic situation is represented.

In identifying processing level of desertification stages differentiation we follow principles of definite type or ratio between correlated components of terrestrial ecosystems, in which the change of one of the components leads to change of the another one, and that causes development of land degradation.

Climatic conditions and vegetation have the strongest influence on development of soil processes among all the complex of its factors. It is possible to say, that majority of common rules, typical for biological objects, influence on soil as on an open bio-stagnant system, as well.

With a high importance of botanic, zoological, hydrological criteria, we consider that the priority in identifying of processing level stages belongs to soil criteria with climatic characteristics. In this connection, on the going stage of the research worth wile to consider the dynamics of soil formation processes and their dependence on parameters of soil climate as a basis. Soil climate parameters, in studied region depend on ways of influence on vegetation cover, determined by density of sheep livestock per unit area. The processes of land surface overheating under the impact of sun radiation permeating inside of soil mass have a strong influence on reformation of organic and mineral parts of soil. We think, that determined for gray semi – desert soil of Central Asia process of reformation of mud particles in the profile is typical stage of desertification.

In condition of soil profile dehydration of loam and clay compositions and weathering of soil mass, organic substances and emitted by them decomposition of carbon dioxide takes part in soil formation. Subsoil dehydration (temperature rise) includes not only degradation processes. In some extend, it contributes to formation of new mineral structures and minerals, unstudied yet.

Peculiarity of soil formation processes in arid conditions is expressed by successiveness of stages with its morphological and physical-chemical properties. Stages of soil properties change are followed by deterioration of agronomic characteristics, decrease of productivity and lose of stability. Such evolution we call regressive evolution, as formation of new properties is followed by staged simplification of structural-functional organization of soil. For illustrating these indexes we use stages of regressive evolution of meadow-chestnut and light-chestnut soil of the Tersko–Kumskaya lowland. In meadow – chestnut soil desertification is connected with salinization, that's why this type of desertification was called halogen-lithogeneous type of desertification.

On background level, the profile is distinctly differentiated on horizons with generally accepted parameters of morphological features. During the first stage of desertification the humid horizon is being lost, as well as structural-functional organization of the profile and subhumid horizon is going on the land surface. In condition of moderate stage of development of regressive evolution humid horizon is blown off, soil forming sediments draw near the surface and, in fact, humid part of the profile is disappearing what entails decrease of biophilic elements' role in turnover and the features of geological turnover are manifested. In strong and very strong stages of regressive evolution, humid cover disappears completely, exposed to destruction and denudation. Analyzing the stage of regressive evolution of light chestnut soil, the same trend is revealed with formation of aeolian – lithogeneous type of desertification. Its stages are differentiated by the degree of expressiveness of the processes of windy erosion and sedimentation. Characteristics of the stages of regressive evolution of light-chestnut soil show diminution of the degree of humidity from 2,5% of the gross contents to 0,5%. The most typical is density of hard phase of the first stage 1,1 – 1,3, in the stage of very strong desertification>1,7, what explained by a high anthropogenic impact, pasture load, influencing by physical density on sediments coming on the land surface. We have to mention reduction of water permeability (mm/h) according to the parameters of desertification degree. The same changes are manifested by the accumulation of vaporous moisture of atmosphere and projective cover of vegetation by the stages of desertification and decrease of plant productivity.

Data, characterizing change of soil climate according to quantity of pasture loads are of considerable interest. Increase of density of 5 pastured sheep heads per hectare (fig.1) entails temperature rise of light-chestnut, middle-loam soil in 0-3 layer to 5-6 ^{0}C in comparison with condition of maximal loads of 1 sheep per hectare. Dynamics of temperature regime change of some layers differs in interval 10-14 ^{0}C. Formed differences result in decrease of moisture stock and nutritious elements, accessible for vegetation . As well as indicators of salinization, erosion and slitization, temperature regime of upper soil horizons serves as limitive factor. Reveal of optimal gradation of soil profile temperature, particularly during dry periods represents one of the most important problems of arid soil formation. It is illustrated by daily variation of temperature (fig. 2) on light-chestnut soil surface. Maximal temperature with maximal difference under 6-8 ^{0}C is formed between variants with optimal load of 1 sheep per hectare and deteriorated parcel with over load >5 sheep per hectare. On the basis of changes, revealed by temperature indicators it is possible to say about formation of essential changes in soil climate under anthropogenic factor. Influence of climatic conditions, contributing to arid degradation is illustrated by vertical zones of development of wind's different speeds on different altitudes. Dust, risen in atmosphere forms 2 tiers: in zone of low speeds it entails sedimentation process, but in zone of high speeds - material transportation in long distances on intercontinental level (fig. 3). We can consider that sands' move from Aral basin reaches coastal parts of the Caspian Sea, forming massifs of moving sands.

Studying of physical properties by desertification stages of light-chestnut soils shows changes of such important indicators as density and water permeability in upper layers. On the background level of desertification processes fold density is characterized by optimal unit 1,0-1,2 with high water permeability 50-60 mm/hour. Gradual increase of desertification processes is revealed according to their stages, mentioned earlier. In stage of very strong desertification density of layer fold is 0-10 cm> 2,0. Essential differences are formed by remote soil indicators. According to intensity of pasturage, particularly, in soil areas with different summarized salt contents in half meter layer of the profile in % (limits of approximate distance). In intensive pasturage salt contents in half meter layer of light-chestnut soils forms 0-0,2%, minimal area 2,2 % , maximal-2,8%. By increase of summarized salt contents in meadow solonchaks to 2 %, minimal area forms 62,3, maximal 62,3 the total area of "mobile" soil areals in intensive pasturage is 1,5%, in moderate pasturage 2 sheep per hectare 4,6, in reserved regime 48,1. According to these data we can conclude that cattle breeding is one of the most important factors of soil formation. In intensive pasturage, "mobile" areals are stabilized on the level of strong desertification, in reserved regime with duration of 10 years, maximal unit of "mobile" areals on the level of low, desertification is formed. The same data are revealed in change of soil areas with different degree of salinization. In intensive pasturage more than 3-5 sheep per hectare of "mobile" areals during 2000-2002 years is about 46,6 %, indicating dynamics character of remote soil indicators. Maximal unit of "mobile" areals differs between moderate level and strong level of soil salinization, that reaches 46,6-52,9%. Soil formation, as phenomenon totality of moving processes is characterized by formation of "mobile", moving areals differentiated by salinization degree, sodicity, erosion, slitization. Formed indicators of soil categories by desertification stages illustrate ratio and unit of soil functioning areas to the total land territory. Borders of soil functioning areas are differentiated in general structure with soil areals under strong desertification impact, where geological sediments came on the surface by wind erosion and contemporary sediments-in condition of salinization and sodicity high development. According to these data very high content of functional soil area is revealed in meadow solonchaks and fixed sands that are in stage of restoration. In stage of transformation to typical solonchaks, light-chestnut solonchaks, meadow solonchaks and meadow-chestnut soils, decrease of FCP to 85-90% is revealed and accordingly increase of areas under desertification impact on high and very high level. Very low content of <70% is typical for light-chestnut, sor, crust soils and solonchaks where desertification is very strong – there are lands without biogeocoenosis cover.

Generalized data about anthropogenic desertification drivers manifest the leading role of processes connected with interaction of open land surface with atmosphere, vegetation cover and formation of geological sediments on the surface.

Atmosphere processes' influence is manifested by the rise of fine earth soil material by wind in atmosphere and its concentration in wet layers, preventing from precipitation. In the same time, temperature gradient is formed and the currents of moisture don't move. Very important factor is data of vegetation cover, increase of areas without vegetation cover and open land surface. These processes contribute to spread of the area occupied by inhabited localities and increase of reflecting ability of soil.

Generalizing results of arid soil formation study, we should note that soil which is influenced by desertification processes, in consequence of radical changes transform in particular taxonomic unit with high diversity of properties, typical for terrestrial ecosystem conditions. That's why we consider that formation of new variety of soil types and new gradient of environmental conditions with different set of properties is elementary act of arid soil land evolution.

Its principle feature – cyclic change of arid ecosystems, of water and geological origins.

Carrying out of fundamental and applied researches of soil formation processes and laws of their changes in conditions of dry regions by the type of soil and non soil formations – presents the basis of worked out scientific direction – "Arid soil formation".

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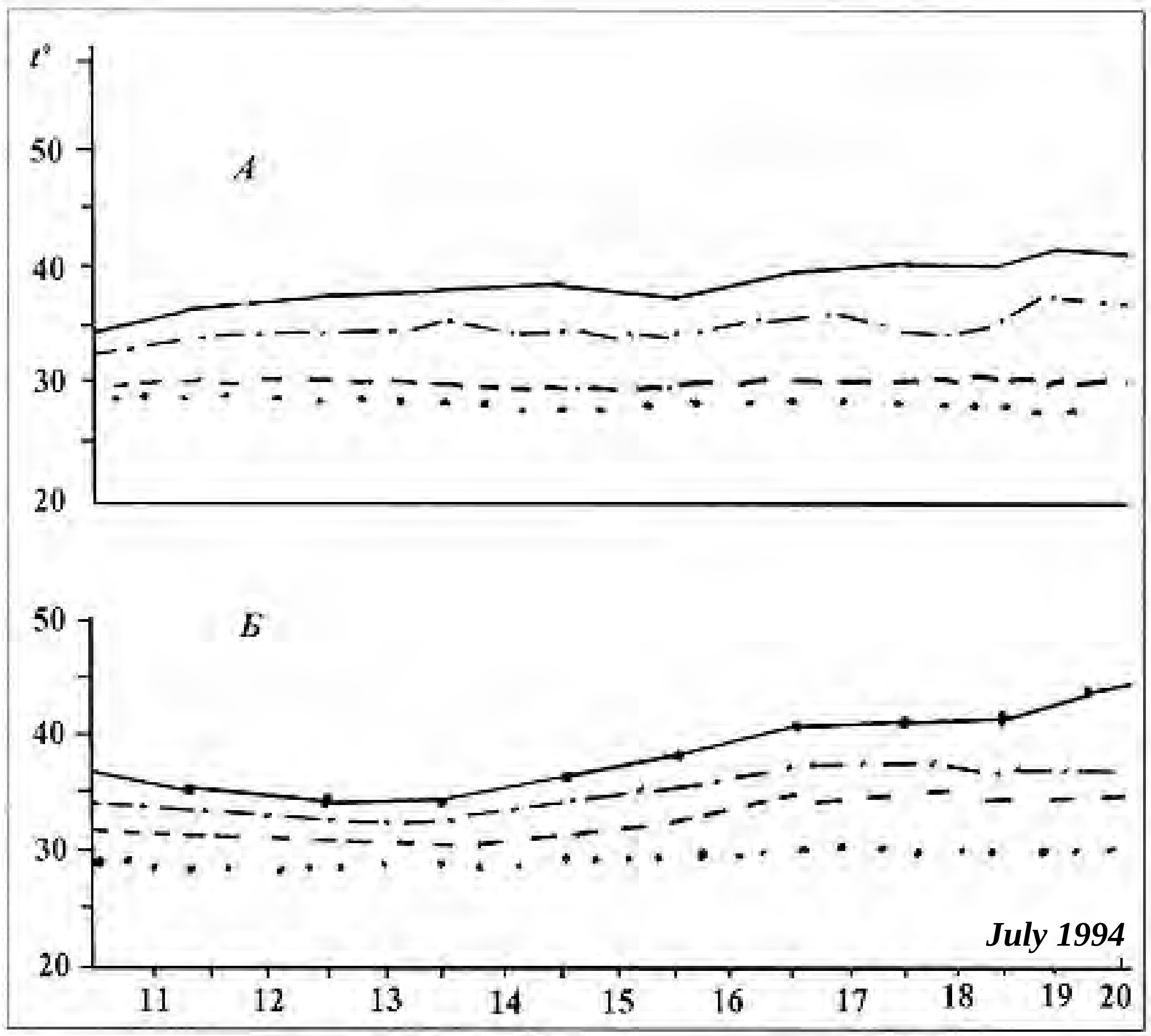

Fig. 1. Maximal temperature of upper layers of light-chestnut middle loam soils of the Tersko-Kymskaya lawland.

А – optimal load 1 sheep/ha

Б – overpusturage in density 1 sheep/ha

———— – soil surface;

– · – · – · –– depth 0-1 cm;

– – – – – ·– -//- 1-3 cm;

.... – -//- 3-5 cm.

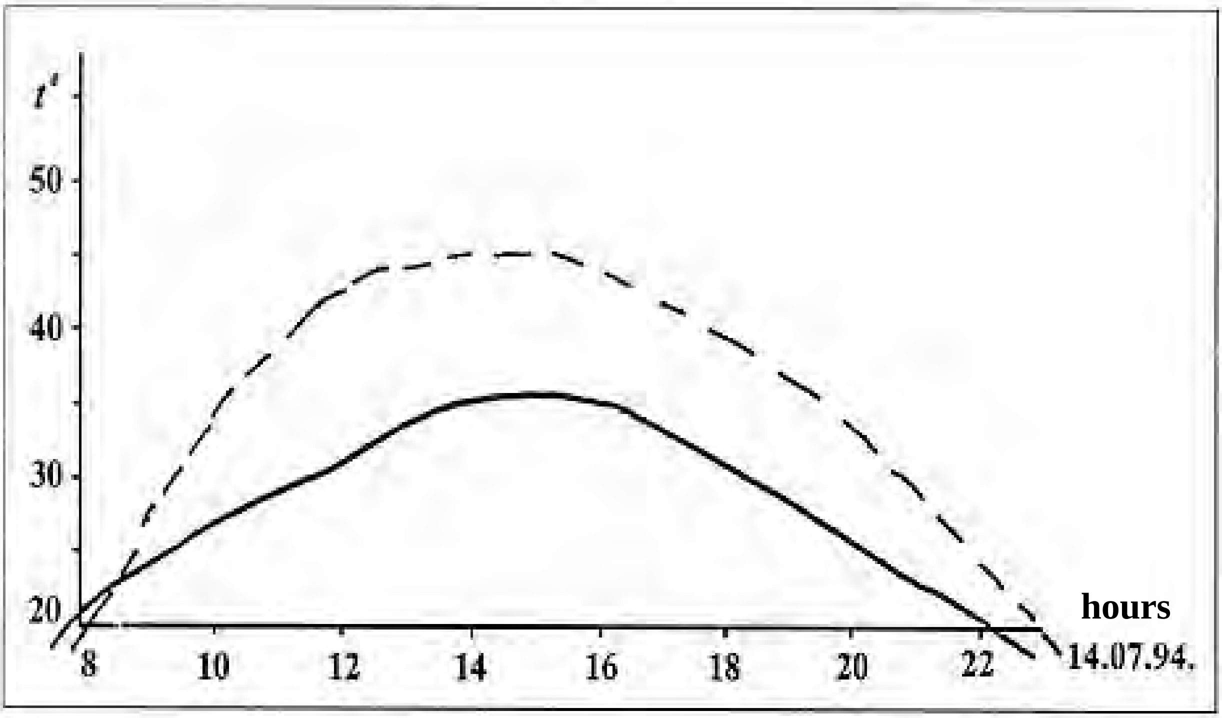

Fig. 2. Daily variation of temperature of the surface of light-chestnut middle-loam soil of the Tersko-Kumskaya lowland:

——————— – optimal load (1 sheep/ha) on soil of ephemera-sagebrush (wormwood) vegetation;

– – – – – – – – deteriorated parcel with over load > 5 sheep/ha.

Zone of high speed

Zone of law speed

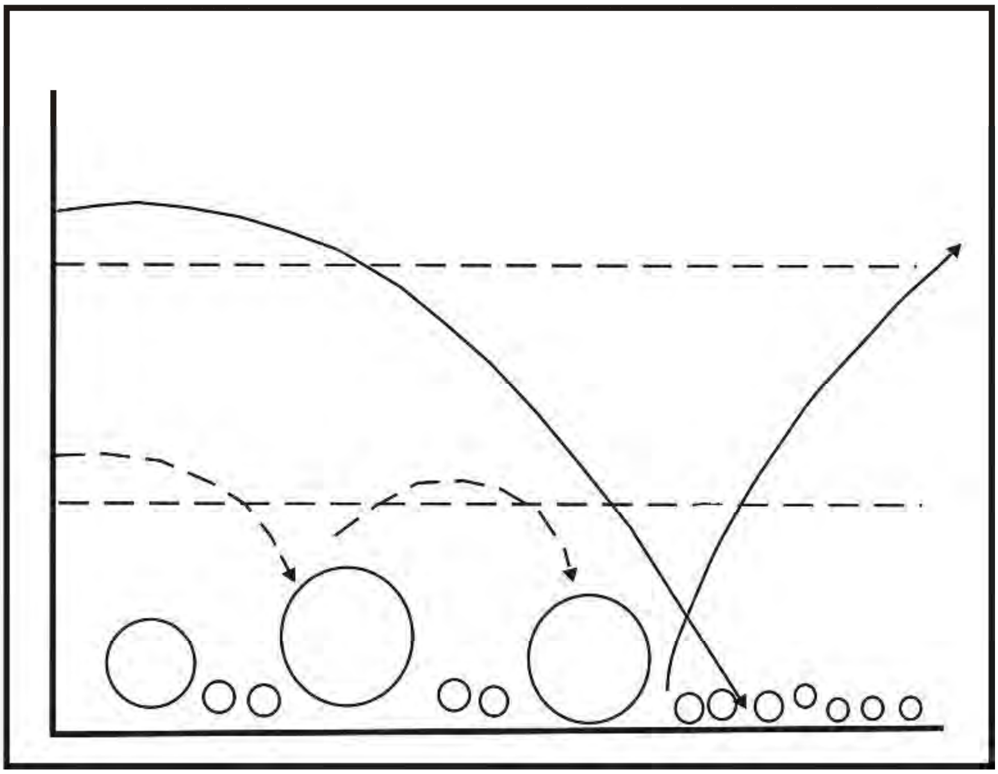

Fig. 3. Zones of different speeps of wind in the Tersko-Kumskaya lowland in light-chestnut soil areal.

================================ **ДОКЛАДЫ** ==================================

ГЕТЕРОГЕННОСТЬ АРИДИЗАЦИИ В ЦЕНТРАЛЬНОЙ АЗИИ В КОНЦЕ 20-ГО ВЕКА

© 2005 г. А.Н. Золотокрылин

Институт Географии РАН, 109017 Москва, Старомонетный переулок 29, Россия

Анализ междесятилетнего изменения климатических факторов и индикаторов аридности на равнинах Центральной Азии с 1982-2001 гг., свидетельствуют о том, что распределение индикатора на большое расстояние совпадает с территориальным перераспределением осадков холодного времени года. Отличительной чертой аридизации было одновременное уменьшение осадков в одном регионе и увеличение в другом, что наблюдалось в течение последних 20 лет. Длительность периода аридизации уменьшается в Прикаспийской низменности, так же как и в некоторых местах на территории между Каспийским и Аральским морями, включая западные территории Аральского побережья. Однако, увеличения в большей части происходит между морями к востоку 60°E меридиана.

Регион, где происходит увеличение длительности периода аридизации, включает Восточные районы вблизи Аральского моря и среднюю часть бассейна реки Сыр-Дарья.

Из результатов этого исследования видно, что изменение регионального климата в Центральной Азии колеблется, согласно специфики субрегионов и поэтому нет оснований предполагать, что тенденция аридизации будет распространяться по всей территории в течение следующего десятилетия.

HETEROGENEITY OF ARIDIZATION OF CENTRAL ASIA AT THE END OF THE 20TH CENTURY

© 2005. A.N. Zolotokrylin

Institute of Geography, Russian Academy of Sciences
109017, Staromonetny per. 29, Moscow, Russia

Introduction

Contemporary desertification of arid lands is increasingly affected by the interactions of natural and anthropogenic factors and their impacts. Of these factors, climate is of the greatest importance. Aridization of climate (climatic desertification) intensifies anthropogenic processes of desertification and makes the appeared ecological crises more profound. The current global warming trend, and after-effects on the major arid regions of the world are not yet clearly understood,. but research increasingly points to regional climate change as a large influential factor.

The investigation is aimed at identification of decadal climate change in the Central Asia between 1982-2001, and its impact upon processes of aridization. Climatic desertification of the territory is estimated with the help of the normalised difference vegetation index (NDVI)-indicator (Zolotokrylin, 2003). This indicator reflects the zonality of heat exchange between arid land and atmosphere as the relation of radiation and evapotranspiration mechanisms in the regulation of thermal conditions of soil surface and the lower layer of the atmosphere (Zolotokrylin, 2002). The peculiar feature of this indicator is the fact that manifestation of climatic desertification is estimated in low-inertia components of ecosystems – vegetation cover and in soil (moisture reserves) on the scale of several decades (phrase removed for clarity). From this point of view, climatic desertification means: (1) reversible loss of part of vegetation cover and (2) degradation of part of vegetation cover with low restoration ability under the conditions of excessive anthropogenic load.

Materials and method

Territory of investigation (the latitude of 40-52o N and the longitude of 43-80o E) covers Central Asia and the adjoining arid lands. Climatic data are presented by daily average air temperature and daily precipitation totals over the period of 1982-2001. Decade statistical parameters of climate are calculated for different months and warm (cold) season, which are then compared. The period from April to October is considered to be warm, and the period from November to March, cold.

In this study, the important index of aridization, such as the number of days with precipitation, and the number of precipitation days of different intensity, was identified. Additionally, monthly precipitation totals and monthly sums of active temperature days (days with temperatures 10oC above the daily average temperature) were calculated. It is known that the sum of active temperature divided by 10 is numerically close to evaporability in millimeters. Then the proportion of sum of precipitation days to sum of active temperature days is recognized as index of humidification known as Selyaninov hydrothermal coefficient (HTC):

$HTC = \sum P / 0.1 \sum_{t>10}$,

Where $\sum P$ denotes precipitation sum, $\sum_{t>10}$ is the sum of active temperatures.

The NDVI-undicator of climatic desertification is defined as the multi-year time interval during vegetative season with NDVI < 0.07. Both indices are calculated for each decade during 1982-2001.

Results

Change of climate in the decade of 1992-2001 as compared with the decade of 1982-1991. Climate and hydrological cycle of the northern parts of the territory (dry steppes, semi-deserts, partially northern deserts) are mainly determined by western transfer, and that of the southern part (northern deserts, southern deserts) - by subtropical circulation. Conventional boundary between these circulations lies approximately at 47°N latitude. Precipitation of the warm period exceed precipitation of the cold one northwards of the latitude of 47°N, but they become smaller than precipitation of the cold period southwards of this latitude.

Territory northwards of the 47° N latitude. Analysis of synoptic conditions proves growth of recurrence of cyclones in the western part of the territory in the cold season and to a lesser degree in the warm season in the last decade. As a result, winters become warmer, annual precipitation increases due to the precipitation of the cold season (Appendix 12, Fig.1). The greatest increase of precipitation occurred in Prikaspijskaya Lowland. Increase of the number of days with precipitation due to poor precipitation (less than 5 mm/day) is also registered there. It should be noted that increase of annual precipitation in the last decade manifests itself approximately up to the longitude of 60o E. Eastwards of this meridian, annual precipitation decreases.

Because of increase of precipitation of the cold season in Prikaspijskaya Lowland annual isohyets shifted southeastwards by 200-300 km. Analysis of drought index – vegetation conditions index (VCI) – proves decrease of droughts duration over the vegetation season (Zolotokrylin and Vinogradova, 2004). Winds of western rhumbs become more frequent in summer (especially in the western part of Prikaspijskaya Lowland) thus hindering atmosphere dust transport from Turanskaya Plain [label on fig. 1. map].

Territory southwards of the latitude of 47 º N. Temperature rises in the second decade mainly in the cold season. But the season of active vegetation becomes cooler, which is confirmed by the decline in the total number of active temperature days and, therefore, decrease of evaporability on the greater part of the territory. The maximum decrease of sums of temperatures by 100ºC and over is observed in the regions between the Caspian and the Aral seas and southwards, including regions adjoining the southern part of the Aral Sea. Decrease of aridity of this territory (increase of HTC from 0.2 to 0.4) in May-June is connected with decrease of the sum of temperatures.

Annual precipitation totals did not change significantly within the study area in the last decade with the exception of the regions eastwards of 60o E longitude including the mountainous part of the Syr-Darya River basin. This basin’s annual precipitation decreased due to noticeable decrease of precipitation in the cold season. Before the beginning of drying out of the Aral Sea, precipitation of warm season prevailed north of the Aral Sea and surrounding it. In the last decade precipitation in the cold and warm seasons is almost equal above bare bottom and the remaining water surface.

Active wind activity in the Aral Sea region in 1970-80s caused sharp increase in number of dust storms and dust transfer to irrigated lands, which resulted in soils salinization (Zolotokrylin, 1996). At the end of the 20th century, the number of dust storms considerably decreased, due to decreases of recurrence of strong winds despite continuing drying out of the Aral Sea.

Estimation of impact of decade climate change upon aridization

Territory northwards of the latitude of 47º N. In the last decade, shortening of the period of aridization is mainly observed in Prikaspijskaya Lowland (Appendix 13, Fig. 2). It is determined by the fact that moisture reserves in soil in winter-spring period increased due to mild winters almost without frosts. Soil freezes very little, and excess of winter precipitation accumulates in soil. Contrast of soil moisture content between micro-lowerings and micro-risings decreased considerably. As a result, restoration of vegetation cover (especially considerable in the west of Prikaspijskaya Lowland) began, which is proved by the analysis of distribution of NDVI-data. Another cause of vegetation re-restoration was a sharp decrease of anthropogenic load at the end of the 20th century. It is worth mentioning that these climate changes took place mainly in dry steppe, semi-desert and partially northern desert regions adjoining the Caspian Sea.

Eastwards of the Prikaspijskaya Lowland, there is a tendency of increase of duration of period with aridization processes is registered (Appendix 13 Fig. 2). It is especially evident on the territory eastwards of the meridian of 60º E.

Territory southwards of the latitude 47 º N. On the territory between the Caspian and the Aral Seas shortening of aridization period alternates with some increase of it (Appendix 13, Fig. 2). Shortening of the period occurred in the regions where at the beginning of vegetation season dryness decreased. Increase of aridization period duration by 0.5 month is more characteristic of the territory eastwards of the Aral Sea where precipitation of the cold season decreased considerably, and days with low-intensity precipitation decreased in number. For example, in the region of lower reach of the Syr-Darya River the aridization period became longer by one month and more.

Discussion of results

Analysis of the results shows that regional climatic system on the whole remains stable in the last decades. Climate change in 1992-2001 decade as compared with 1982-1991 decade reflects cyclic increase of intensification of regional circulations, but does not point to shift of their trajectories, i.e. the beginning of stable change. Boundary between regional circulations remains stable. Climatic boundaries (meridional gradients of climate characteristics) correspond to the boundaries of natural zonality. We can say that observed change of climate humidity in the northern and southern parts of the territory is the recurrent fluctuation of regional circulations. There is not enough long-term evidence yet to state that this climate change has stabilized, although it can be considered to be a regional manifestation of global warming. Causes of variability of regional circulations can be different including increase of anthropogenic greenhouse gases in the atmosphere.

As is clear from the data analysis of the precipitation during the cold season and the number of days with precipitation, which form moisture reserves in soil at the beginning of vegetation season, change to the greatest extent. Regions of both increase and decrease of precipitation form simultaneously on the territory. Inter-decade change of precipitation and their frequency determine increase of duration of the period with aridization processes in the regions northwards, eastwards and southeastwards of the Aral Sea. It is important to note that this period does not practically change in the observed delta landscapes of Amu-Darya River Basin.

Observed decreases of precipitation during the cold season in the Syr-Darya basin, especially in its mountainous regions, increases the duration of aridization period in delta landscapes, such as in lower and middle course of the Syr-Darya and has caused the Aral Sea crisis to be more profound.

Strong non-linear responses of dynamic processes in delta landscapes to climate fluctuations (small accidental deviations of climate can cause considerable cyclic changes in dynamic components of landscape) is the cause of changes of water regime, vegetation, level of inland lakes, etc. for many years. Non-linear responses to extreme climatic phenomena are especially dangerous in populated regions where use of natural resources has become unsustainable. For example, the populated regions of the Amu-Darya and Syr-Darya River basins, where irrational economic activities since the 1950's have provoked the Aral Sea crisis.

Conclusion

Analysis of inter-decade change of climate characteristics and indicators of aridity on the plains of Central Asia from 1982-2001 testifies to the fact that indicator distribution to a great extent agrees with territorial redistribution of cold season precipitation. The peculiar feature of aridization in this region was that simultaneous decreases and increases in precipitation were observed. The duration of the aridization period decreases in the Prikaspijskaya Lowland, such as in some places of the territory between the Caspian and the Aral seas including the western areas adjoining the Aral Sea, but increases eastwards of the 60 º E meridian. The regions of increase of duration of aridization period include the eastern regions near the Aral Sea and the middle course of the Syr-Darya River Basin.

From this study's observations, regional climate change in Central Asia is variable according to specific subregions, though in the regions where intense aridization has occurred, this trend will continue through the next decade.

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ПРАВИЛА ДЛЯ АВТОРОВ

Статьи, направляемые в журнал "Аридные экосистемы", должны удовлетворять следующим требованиям.

1. Статьи должны содержать сжатое и ясное изложение современного состояния вопроса, описание методики исследования, изложение и обсуждение полученных автором данных. Статья должна быть озаглавлена так, чтобы название соответствовало ее содержанию.
2. Статьи, поступающие для публикации, обязательно должны иметь направление от учреждения, в котором выполнена данная работа.
3. Объем статьи не должен превышать 15 страниц текста. Размер текстового поля для формата страницы А4 170 x 245 мм должен иметь поля 2.5 см сверху и снизу, 2 см - справа и слева. Статью печатать на компьютере в программе Word Windows через 1.5 интервала. Для заголовка статьи предлагается использовать шрифт Times New Roman 14, для основного текста - Times New Roman 12, или любой другой близкий по строению шрифт. Величина абзационного отступа основного текста статьи должна соответствовать 0.7 см. Текст набирается без переносов с использованием стандартного разделения между словами, равного одному пробелу. Страницы нумеровать в верхнем правом углу листа.
4. Статьи представляют в двух экземплярах. В левом верхнем углу первой страницы рукописи следует проставить соответствующий содержанию индекс УДК. После заголовка ставятся инициалы и фамилии авторов, на следующей строке следует указать **название организации с полным указанием почтового адреса [почтовый индекс, страна, город, улица, дом. почтовый ящик, Б-mail (если есть) и т. д.].** Все страницы рукописи с вложенными таблицами (следующий лист после первой ссылки на таблицу) должны быть пронумерованы. Отдельно следует приложить аннотацию, переведенную на английский язык объемом не более 1 стр.
5. Таблицы должны представляться в минимальном количестве (не более 3-4 таблиц), каждая таблица на отдельном листе. Объем таблиц не более 1 машинописной страницы. Не допускается повторение одних и тех же данных в таблицах, графиках и тексте статьи. К таблицам должны быть даны названия. Все таблицы должны быть набраны в табличной форме Word for Windows.
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8. Список цитируемой литературы следует оформлять в соответствии с ГОСТом 7.1 – 76. "Библиографическое описание произведений печати". Работы располагаются в алфавитном порядке, по фамилиям авторов. Сначала идут работы на русском языке, затем - на иностранных языках. Отдельные работы одного и того же автора располагаются в хронологической последовательности. Для журнальных статей указываются фамилии и инициалы авторов, название статьи, название журнала, год издания, том, номер (выпуск), страницы; для книг- фамилии и инициалы авторов, название книги, город, издательство, год издания, общее количество страниц. Допускаются только общеизвестные сокращения, В тексте, в круглых скобках, указывается фамилия автора и год работы, на которую дается ссылка. Все приведенные в статье цитаты должны быть выверены по первоисточникам. Указание в списке литературы всех цитируемых работ в статье обязательно. Список литературы пронумеровать и печатать на отдельной странице.

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Тел. (095)135-70-41,
Факс(095) 135-54-15,
E-mail: novikova@aqua.laser.ru, jannaKV@yandex.ru

367025, Махачкала, ул. Гаджиева, д. 45 Тел. (8722) 67-60-66, 67-09-83
Факс (8722) 67-09-83
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Fax:(495)135-54-15
E-mail: novikova@aqua.laser.ru,
jannaKV@yandex.ru

367025, Mahachkala, Gadjieva St. bid. 45
Tel. (8722) 67-60-66, 67-09-83.
Fax: (8722) 67-09-83
E-mail: pibrdncran@iwt.ru

ПРИЛОЖЕНИЕ
APPENDIX

Приложение 1. КУИНГДОНГ ШИ, ДЖИАГВО КИ, КСИАОЛИНГ ПЭН, ГУАНГУИ ЛЬВИ, КИНГСАН ШИ, ХЕЙЯН ЛУ.
Appendix 1: QINGDONG SHI, JIAGUO QI1, XIAOLING PAN, GUANGHUI LV, QINGSAN SHI, HAIYAN LU.

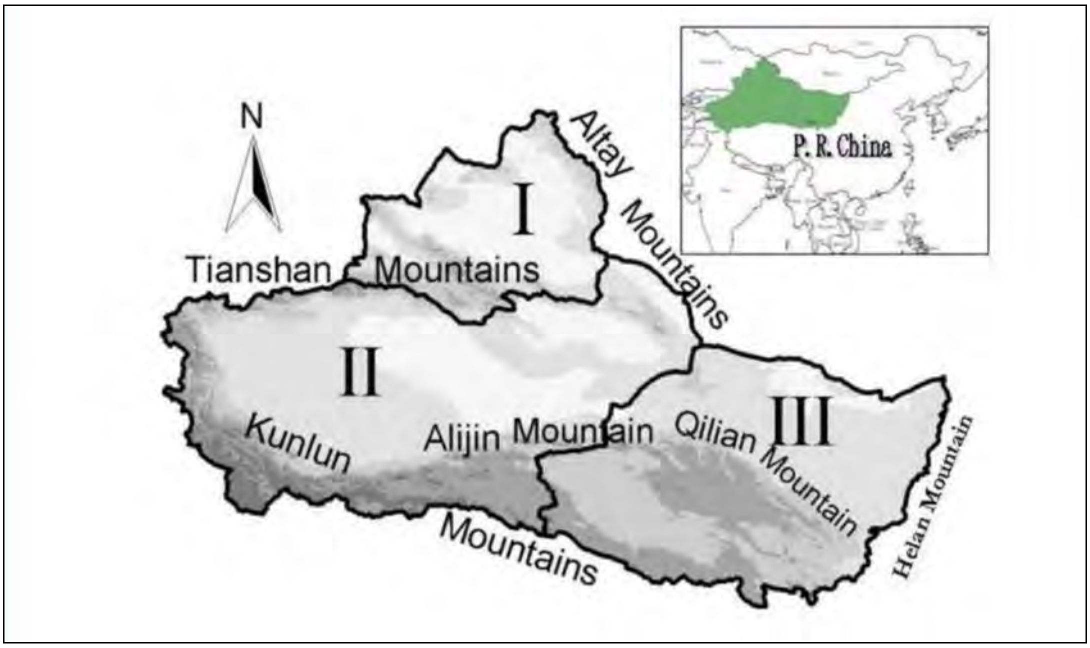


Рис. 1. Географическое положение и суб-климатические зоны изучаемой территории:
I – Алтай Западная зона Тянь-Шань; II – Восточная зона Тянь-Шань Тарум бассейн; III – высота Квайдаму бассейн – Алькса зона пустыни.
Fig. 1. Geographic locations and sub-climate zones of study area: I. Altai-West Tainshane zone; II. East Tainshan-Tarim Basin zone; III. Qaidamu high basin-Alxa desert zone (Qinghai-Gansu-NeiMeng).

Приложение 2: КУИНГДОНГ ШИ, ДЖИАГВО КИ, КСИАОЛИНГ ПЭН, ГУАНГУИ ЛЬВИ, КИНГСАН ШИ, ХЕЙЯН ЛУ.
Appendix 2: QINGDONG SHI, JIAGUO QI1, XIAOLING PAN, GUANGHUI LV, QINGSAN SHI, HAIYAN LU.

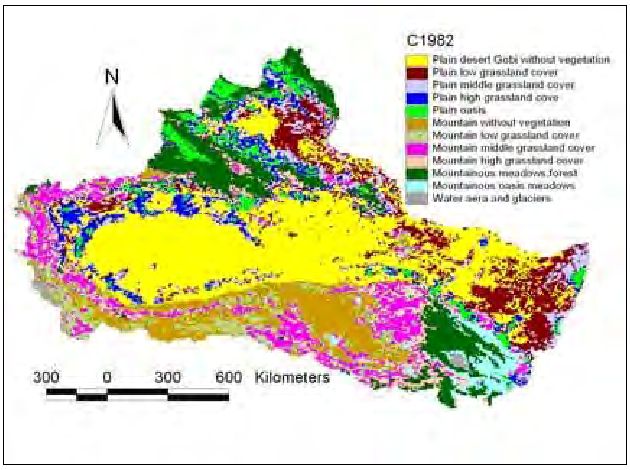


Рис. 2. Карта классификации растительности 1982 г.
Fig. 2. The vegetation classification map in 1982.

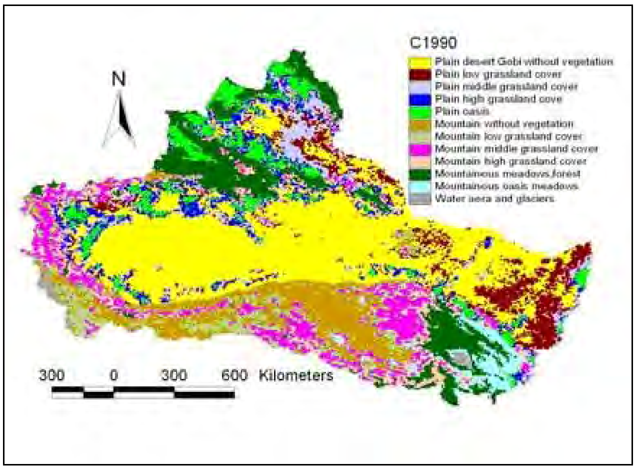


Рис. 3. Карта классификации растительности 1990 г.
Fig. 3. The vegetation classification map in 1990.

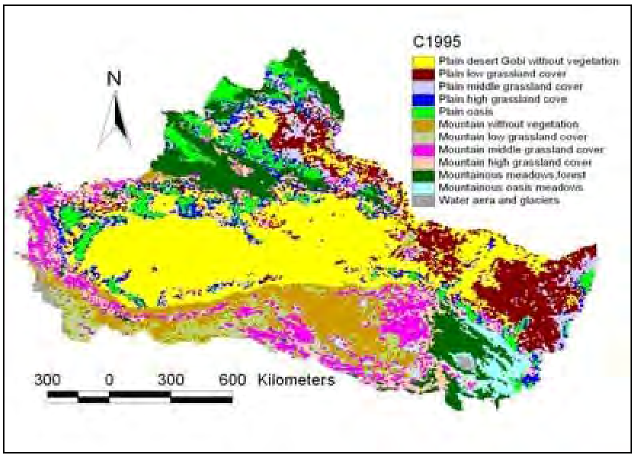


Рис. 4. Карта классификации растительности 1995 г.
Fig. 4. The vegetation classification map in 1995.

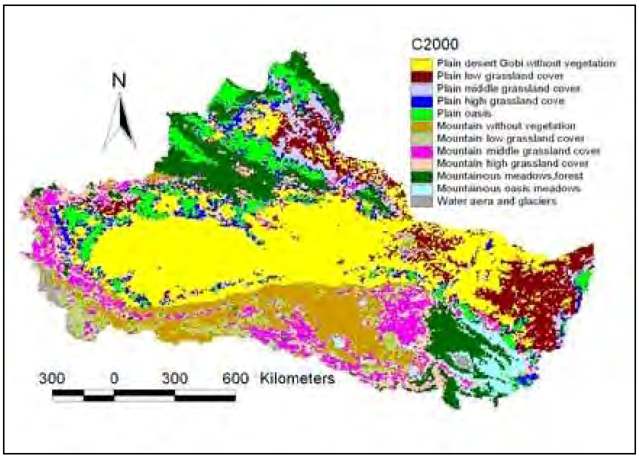


Рис. 5. Карта классификации растительности 2000 г.
Fig. 5. The vegetation classification map in 2000.

Приложение 3: КУИНГДОНГ ШИ, ДЖИАГВО КИ, КСИАОЛИНГ ПЭН, ГУАНГУИ ЛЬВИ, КИНГСАН ШИ, ХЕЙЯН ЛУ.

Appendix 3: QINGDONG SHI, JIAGUO QI1, XIAOLING PAN, GUANGHUI LV, QINGSAN SHI, HAIYAN LU.

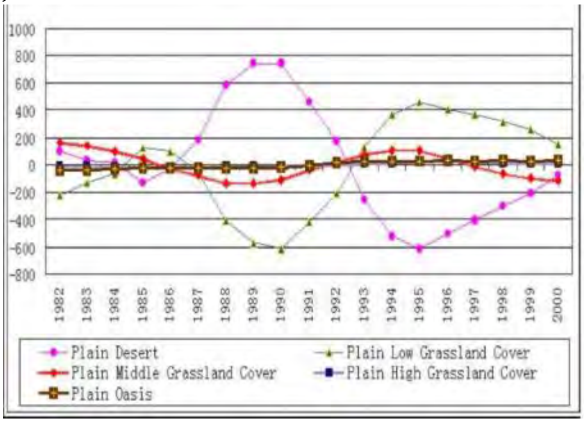


Рис. 6. Аномалии типов растительности в Хекси коридор – Алькси равнине.
Fig. 6. Anomalies of vegetation.

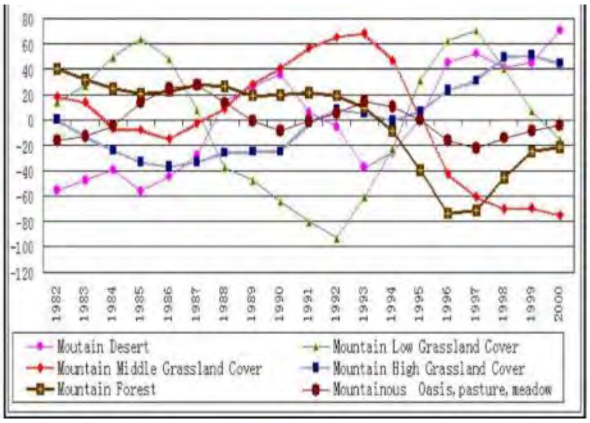


Рис. 7. Аномалии типов растительности на равнине в высоком бассейне Квайдаму. **Fig. 7.** Anomaly of vegetation types in Hexi Corridor-Alxi Plain in Qaidamu High Basin Mountain.

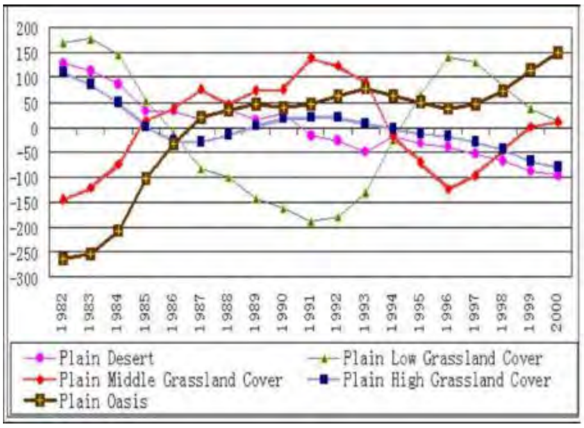


Рис. 8. Аномалии типов растительности на севере равнины Ксинджианги.
Fig. 8. Anomalies of vegetation.

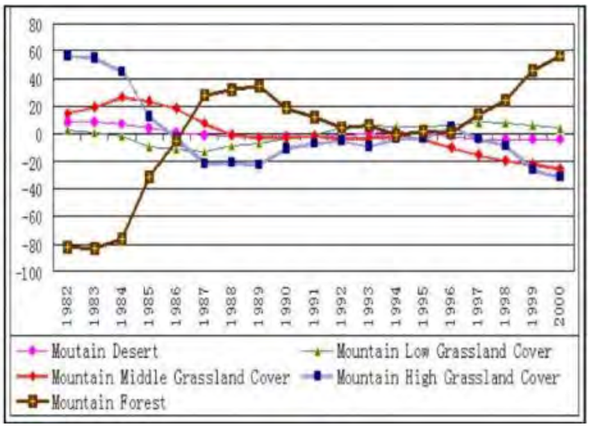


Рис. 9. Аномалии типов растительности на равнине северного Ксинджианга. **Fig. 9.** Anomalies of vegetation types in North Xinjiang Plain in North Xinjiang.

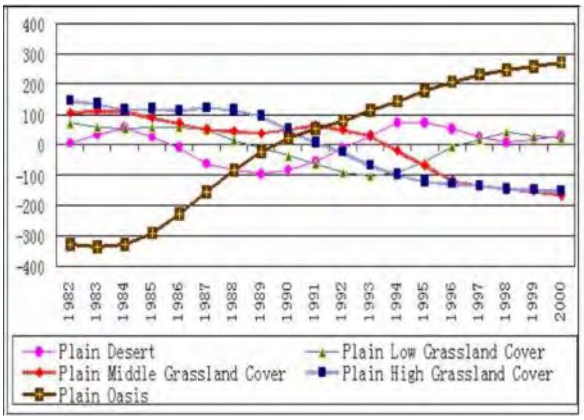


Рис. 10. Аномалии типов растительности на юге равнины Ксинджианг.
Fig. 10. Anomalies of vegetation types in South Xinjiang Plain.

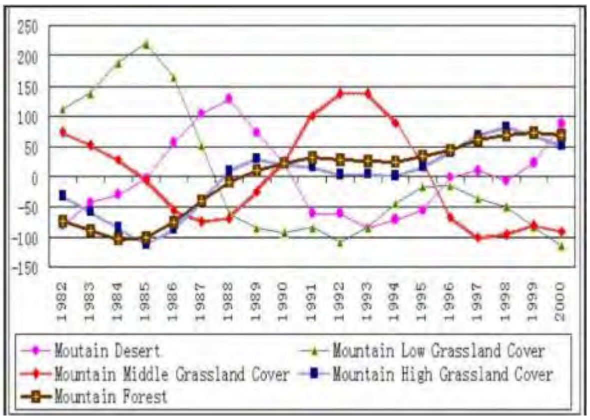


Рис. 11. Аномалии типов растительности на юге равнины Ксинджианг.
Fig. 11. Anomalies of vegetation types in South Xinjiang Plain.

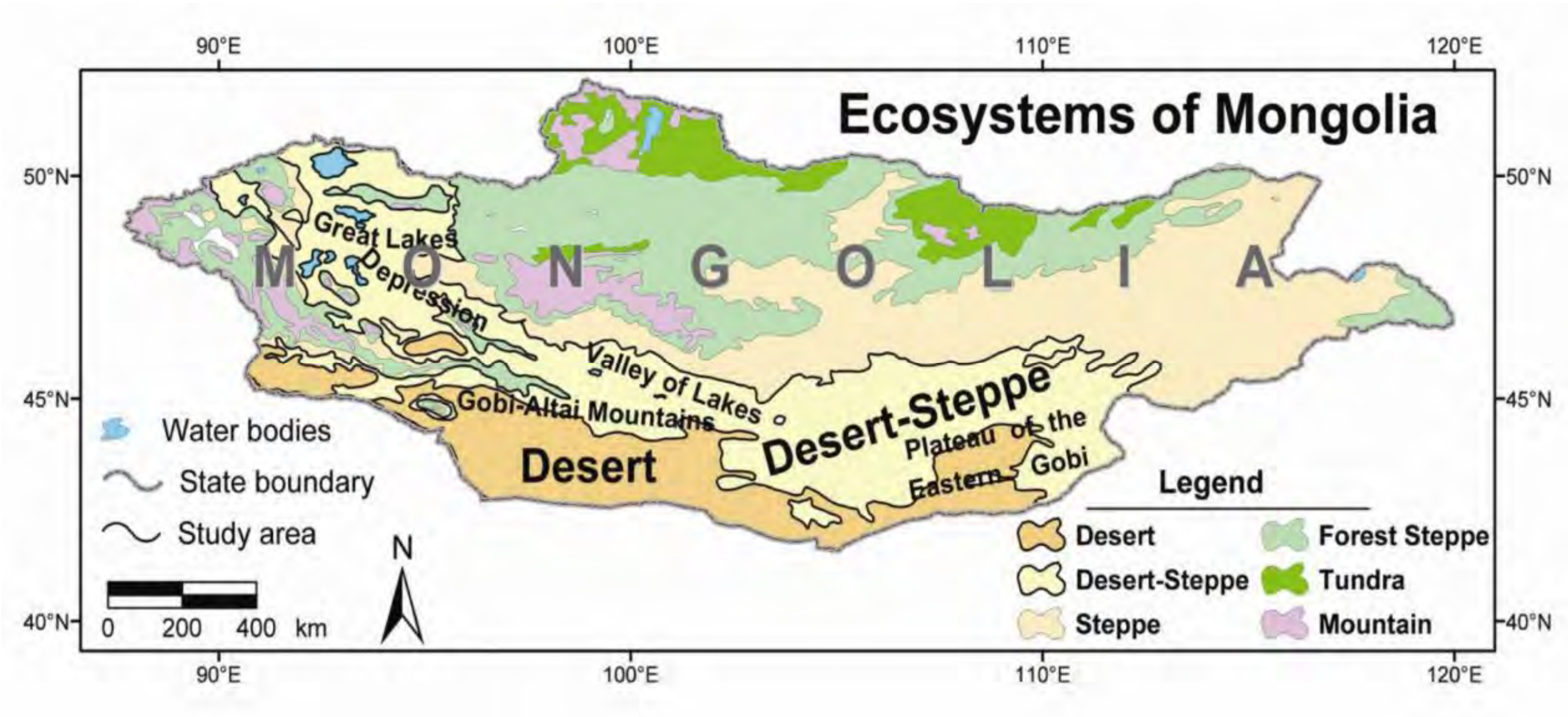


Рис. 1. Экосистемы Монголоии.
Fig. 1. Ecosystems of Mongolia.

Приложение 5: БАЯРЖАГАЛ И КАРНЕЛЛИ
Appendix 5: BAYARJARGAL AND KARNIELI

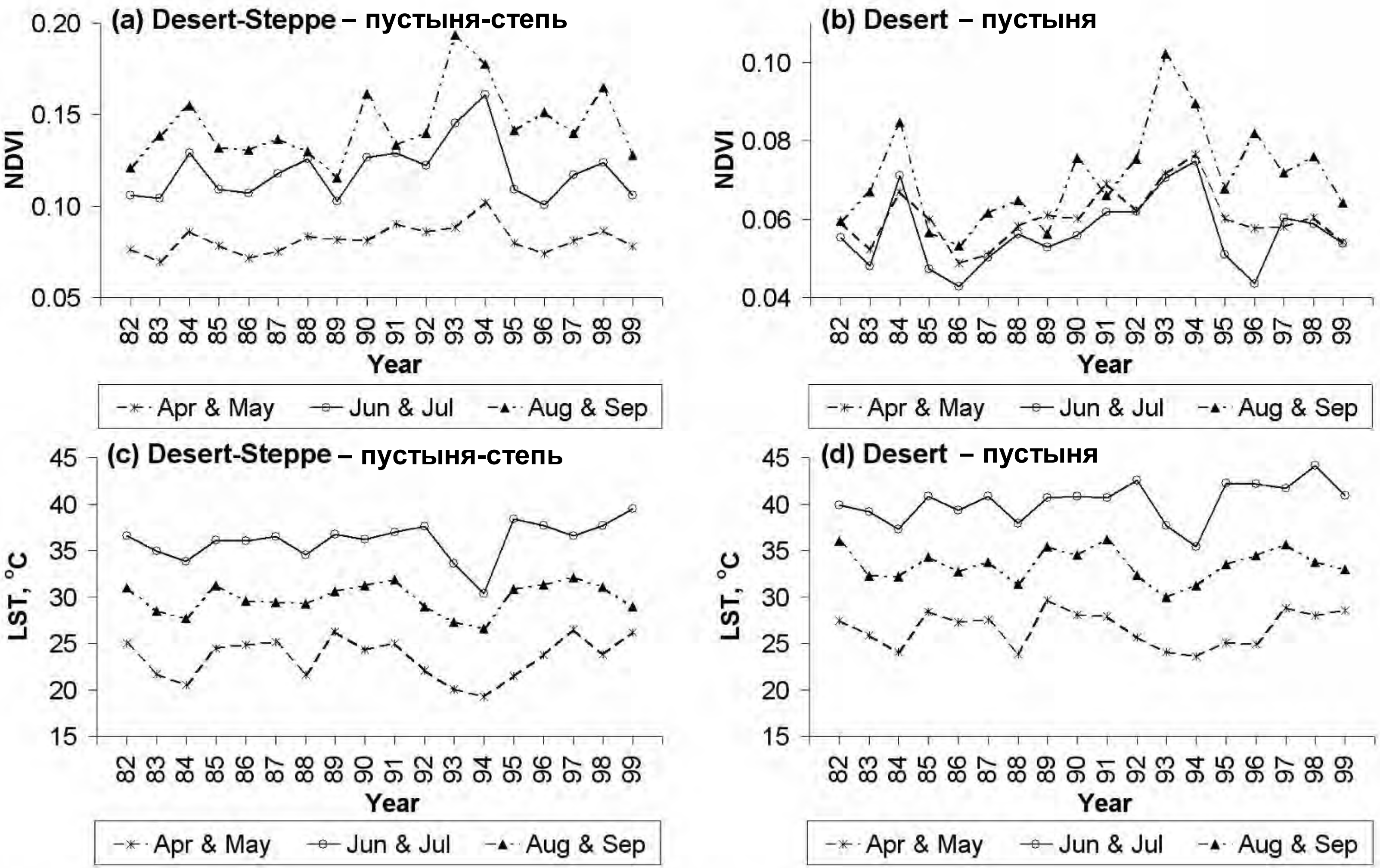


Рис. 2. Межгодовые колебания NDVI и LST в течении трех суб-периодов вегетативных сезонов в течении 18 лет в экосистемах степной пустыни и пустыни.

Fig. 2. Inter-annual variations of NDVI and LST for the there sub-perods of growing seasons during 18 ears in the Desert-steppe and Desert ecosystems.

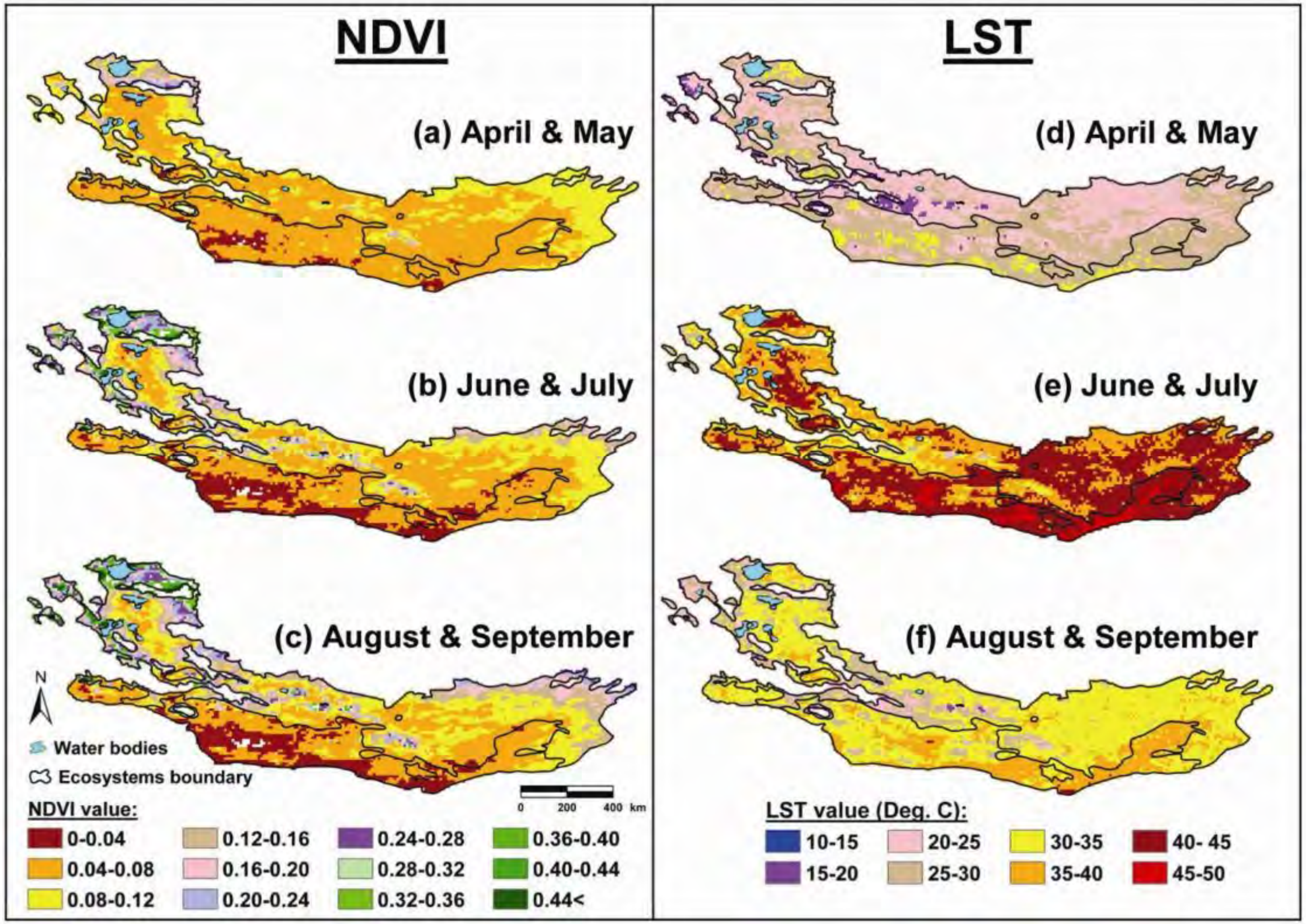


Рис. 3. Пространственное распределение индекса NDVI и LST в течение 18 лет в суб-периоды вегетационного сезона в степных-пустынных и пустынных экосистемах.

Fig. 3. The spatial of the 18 year mean NDVI and LST values in Sub-periods of the growing-season over the Desert-Steppe and Desert ecosystems.

Приложение 7: БАЯРЖАГАЛ И КАРНЕЛЛИ
Appendix 7: BAYARJARGAL AND KARNIELI

влажный год **сухой год** **нормальный год**

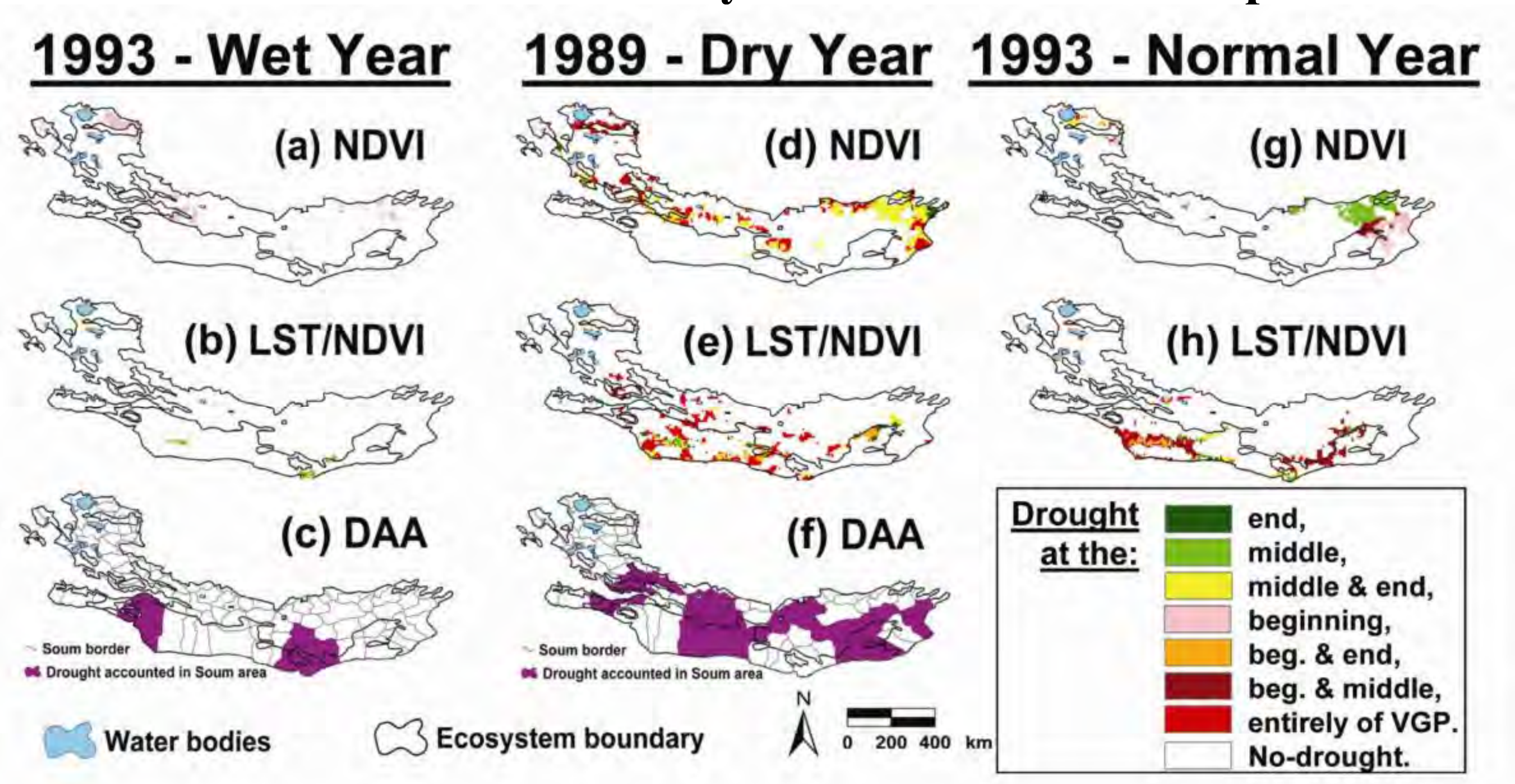
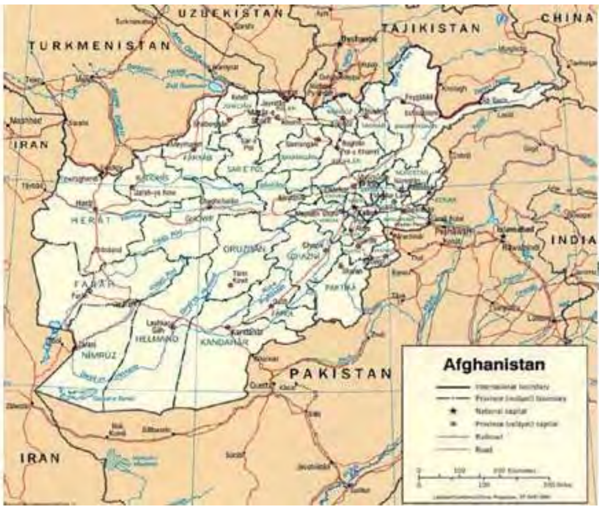


Рис. 4. Пространственное распределение территорий засухи определенных двумя различными индексами полученными NOAA-HUNRR термическая структура данных отражения в течении представленных 3-х лет влажный, сухой, нормальный, в степных - пустынных экосистемах Монголии.

Fig. 4. Spatial distribution of draught accurred areas detected by the two different draught indices derived from the NOAA-HVHRR reflective and thermal dataset over the VGP for three representative years, wet, dry, normal in the Desert-Steppe ecosystems of Mongolia.

Приложение 8: ДЖИАГВО КИ, ДЖОН РЭНДЖИТ, ДЖИАНЛОНГ ЛИ
Appendix 8: JIAGUO QI, RANJEET JOHN, JIANLONG LI

а



б

c

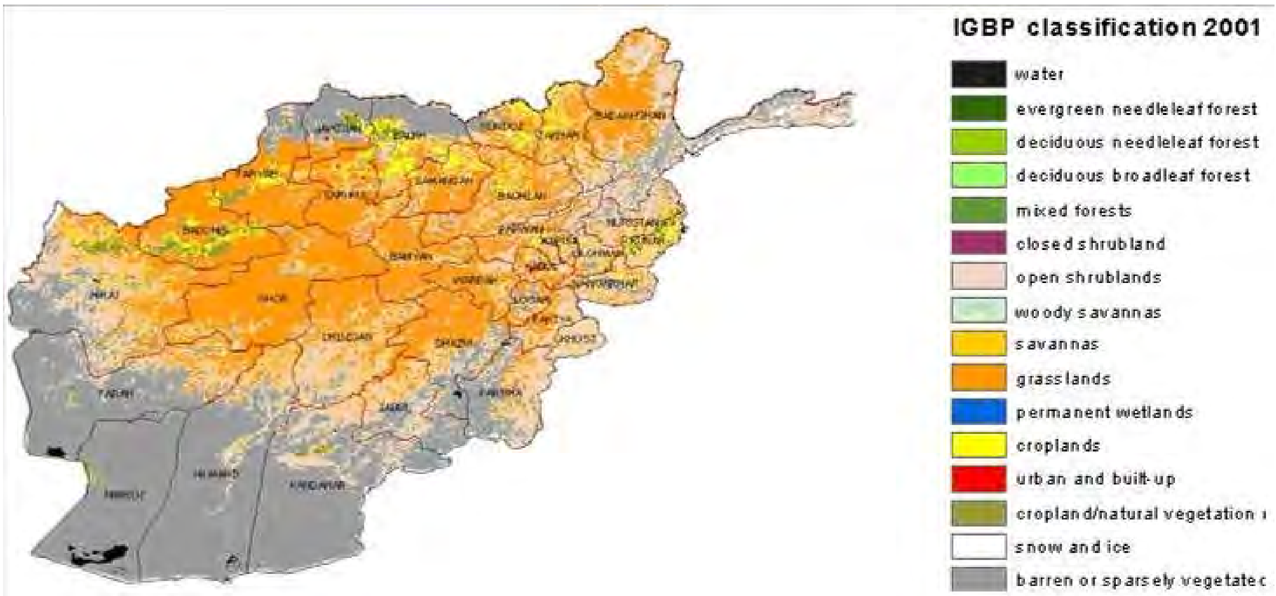


Рис. 1. а) Карта Афганистана и окружающих его стран; б) снимок MODIS с данными в сентябре 2002 г.; с) Использование земли и почвенного покрова страны.
Fig. 1. Map of Afghanistan and its surrounding countries (a), MODIS image acquired on 6 September 2002(b), and the land use and land cover (c) of the country.

Приложение 9: ДЖИАГВО КИ, ДЖОН РЭНДЖИТ, ДЖИАНЛОНГ ЛИ
Appendix 9: JIAGUO QI, RANJEET JOHN, JIANLONG LI

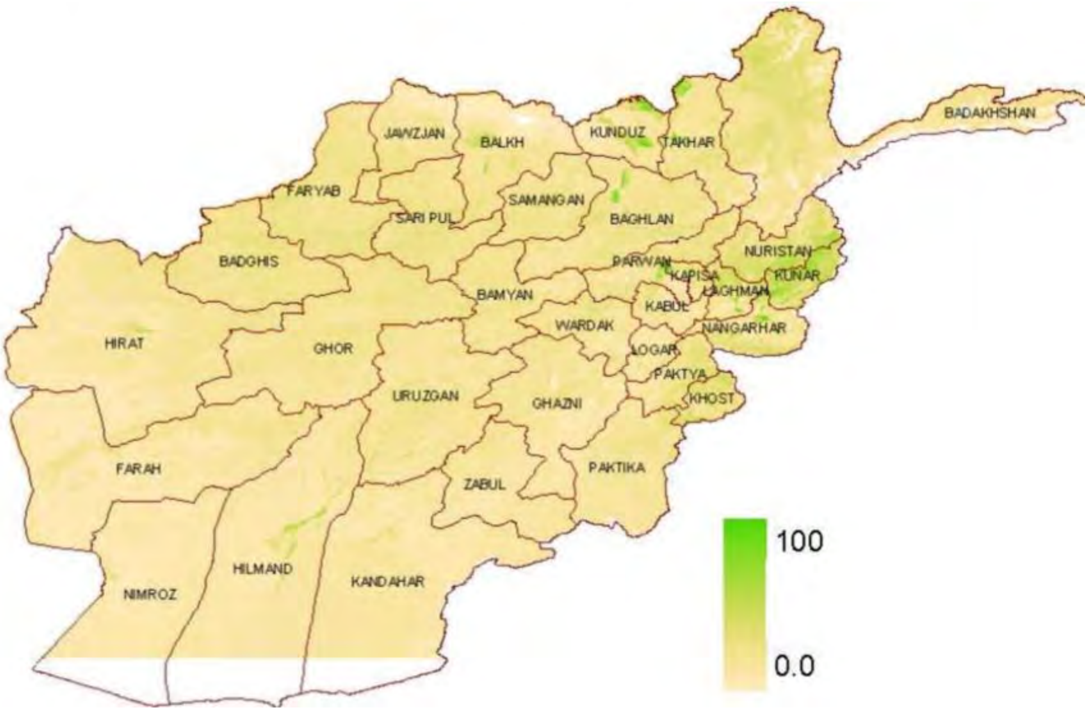


Рис. 2. Фракциональный общий растительный покров Афганистана со снимков MODIS с 8.29.2002 – 9.13.2002.
Fig. 2. Fractional total vegetation cover of Afghanistan derived from a composited 3 MODIS image from 8/29/2002 – 9/13/2002.

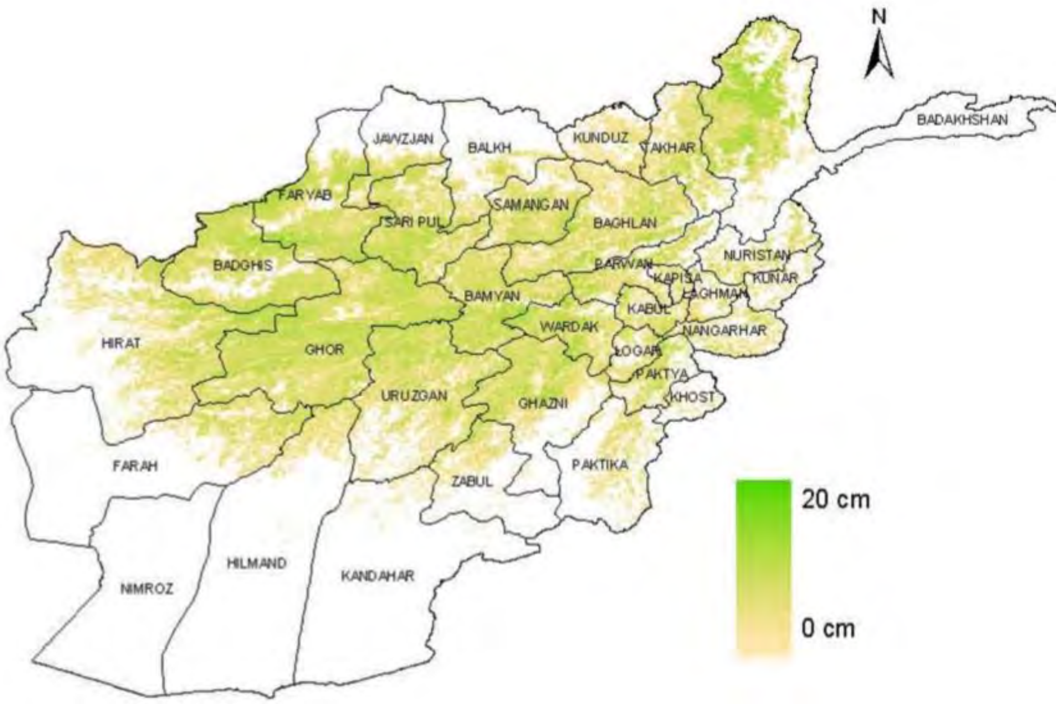


Рис. 3. Высота кормовой растительности от его границ во внутрь страны Афганистана, используя данные MODIS в сентябре 2002 г.
Fig. 3. Forage height overlaid with Province boundaries for the entire Afghanistan using 6 MODIS images acquired on September, 2002.

Приложение 10: ДЖИАГВО КИ, ДЖОН РЭНДЖИТ, ДЖИАНЛОНГ ЛИ
Appendix 10: JIAGUO QI, RANJEET JOHN, JIANLONG LI

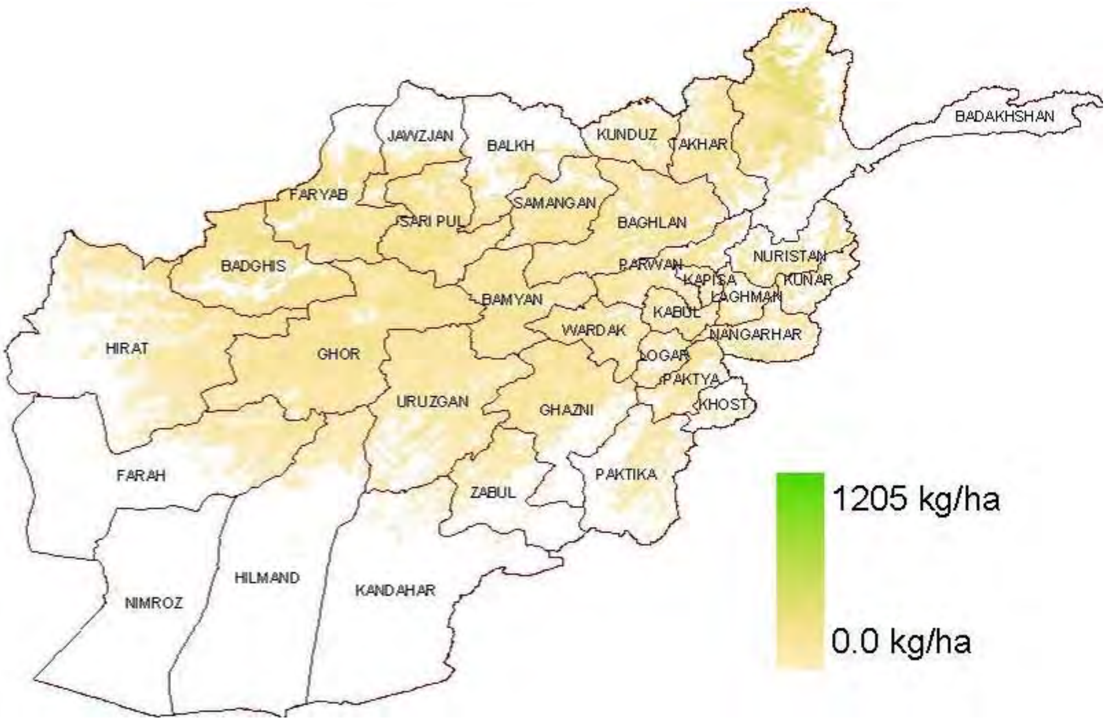


Рис. 4. Кормовая биомасса ландшафтов Афганистана со снимков MODIS между 8.29.2002 – 9.13.2002.
Fig. 4. Forage biomass of Afghanistan derived from MODIS image acquired through 3 8/29/2002 – 9/13/2002.

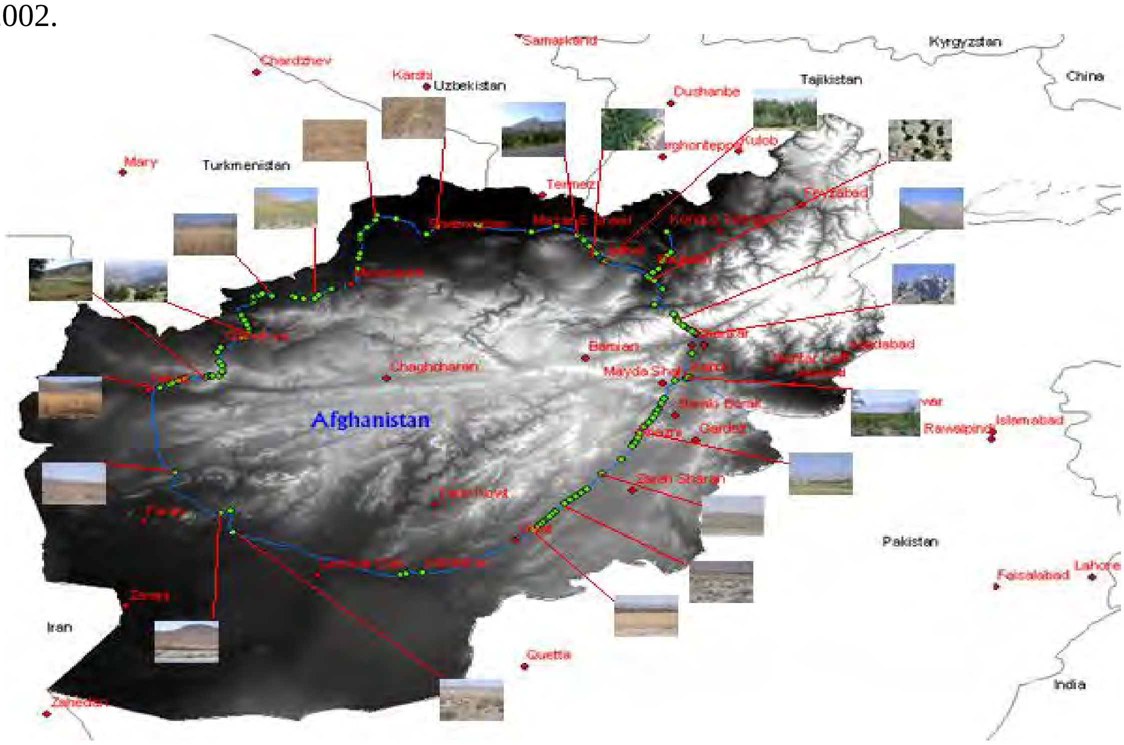


Рис. 5. Обзор полевого маршрута проведенного с июня 15-30, 2003, расположения GPS с фотографиями для подтверждения.
Fig. 5. The field survey route made from June 15-30, 2003, and the GPS locations with 7 photographs used for validation and verification.

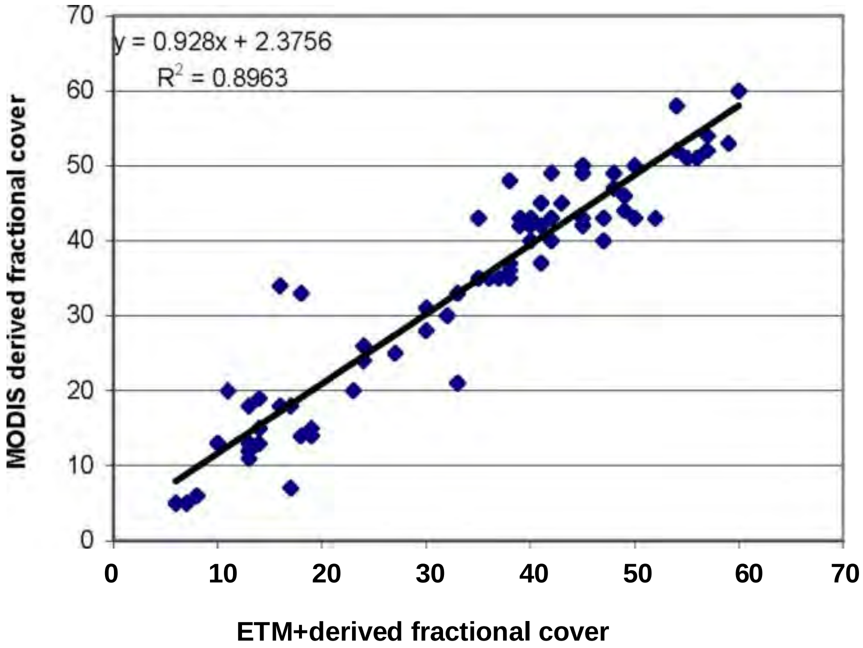


Рис. 6. ETM +зеленый фракциональный покров по версии MODIS 250 м.
Fig. 6. ETM + derived green fractional cover versus MODIS 250m derived fractional cover.

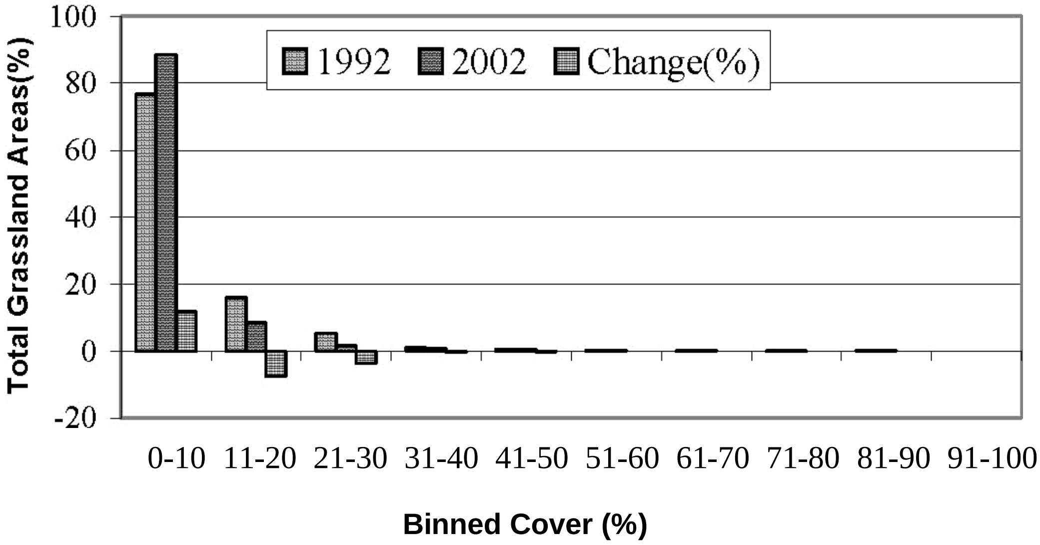


Рис. 7. Процентное содержание растительного покрова до и после власти Талибан с 1992 по 2002 гг.
Fig. 7. The percentage vegetative covers prior and post Taliban Rule, and changes from 1992 to 2002.

Приложение 12: ЗОЛОТОКРЫЛИН
Appendix 12: ZOLOTOKRYLIN

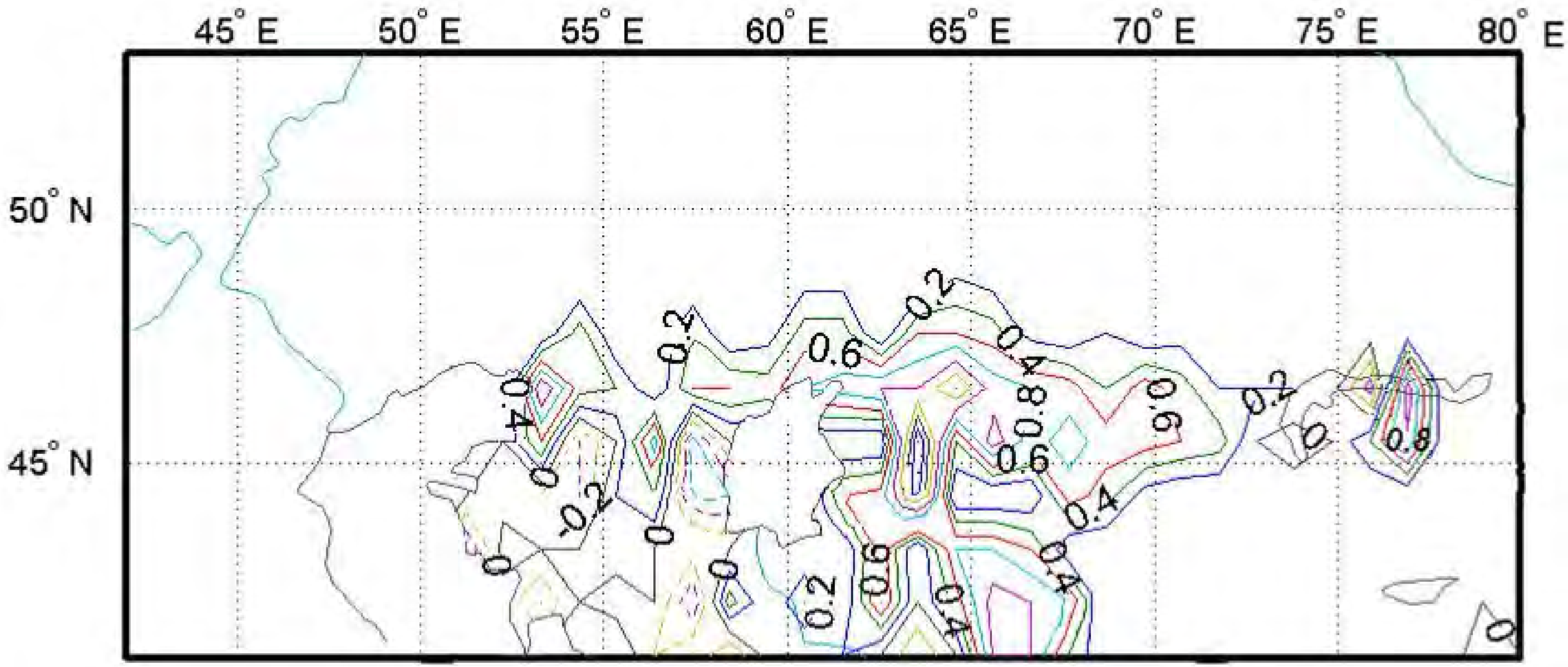


Рис. 1. Географическое распределение осадков холодного сезона (в мм) в Центральной Азии между 1982-1991 и 1992-2001 ноябрь-март. Положительное значение имеет большее количество осадков в 1992-2001 по сравнению с 1982-1991.
Fig. 1. The geographical distribution of the difference of cold season precipitation (in mm) in Central Asia between 1982-1991 and 1992-2001. November - March. The positive values represent higher precipitation in 1992-2001 than during 1982-1991.

Приложение 13: ЗОЛОТОКРЫЛИН
Appendix 13: ZOLOTOKRYLIN

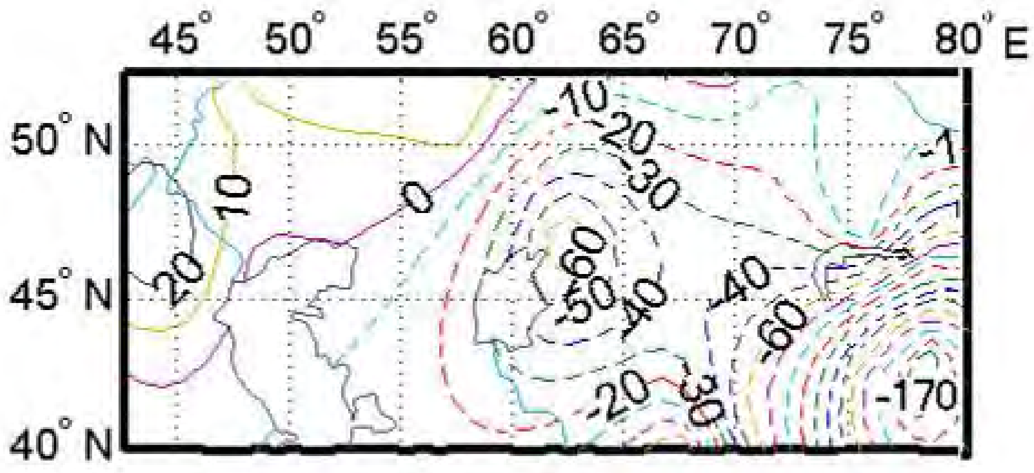


Рис. 2. Географическое распределение NDVI показателя опустынивания (в месяц за год) в Центральной Азии между 1982-1991 и 1992-2001, Май-Сентябрь. Положительное значение имеет увеличение периода аридизации с 1992-2001 в сравнении с 1982-1991.
Fig. 2. The geographical distribution of the difference of the NDVI-indicator of aridization (in months per year) in Central Asia between 1982-1991 and 1992-2001, for May-September. The positive values represent increase of the aridization period in 1992-2001 as compared to 1982-1991.