# Wood resources management: A case study of the Aral region, Kazakhstan

# カザフスタン国アラル地域における森林資源管理

2019 年

地球環境学舎　地球環境学専攻　陸域生態系管理論分野

松井　佳世

## Contents

# Chapter 1

# Introduction

## 1.1. General

Arid and semi-arid areas account for a significant proportion of the terrestrial land and provide the habitat and natural resources for a large population of flora and fauna and humans. Even under a severe water environment, a unique ecosystem of arid lands is the foundation for local livelihoods, through the provision of ecosystem services such as woods for fuel, animal fodder, regulation of land degradation and recreational benefits. Appropriate resource management to maintain regional ecosystems including human livelihood activities related to nature is of extreme importance considering that the soil and vegetation under an arid climate are highly vulnerable and susceptible to human activities and climate change. Building compatibility between conservation and resource utilization is required although these two demands often have conflicting perspectives. To achieve this requirement, it is necessary to promote technical and scientific cooperation to combat desertification. However, to use technology effectively it is necessary to enhance the affinity between the socio-ecological features of the target area and coping techniques. In other words, appropriate technology is determined by the actual condition of people's lives including their awareness of the problem and their needs as well as the social and political demand of the target area.

Kazakhstan has 12.3 million ha of forest land, 49.6% (6.1 million ha) of which is the Haloxylon desert, which is dominated by a *Haloxylon* species called saxaul (Meshkov *et al.*, 2009). Saxaul forests play an important role in maintaining an arid ecosystem, not only by providing habitat for other animals and plants but also by serving as a source of fuel and fodder for human life. Therefore, the disappearance of such forests leads to the collapse of the foundation of life for animals, plants and human beings.

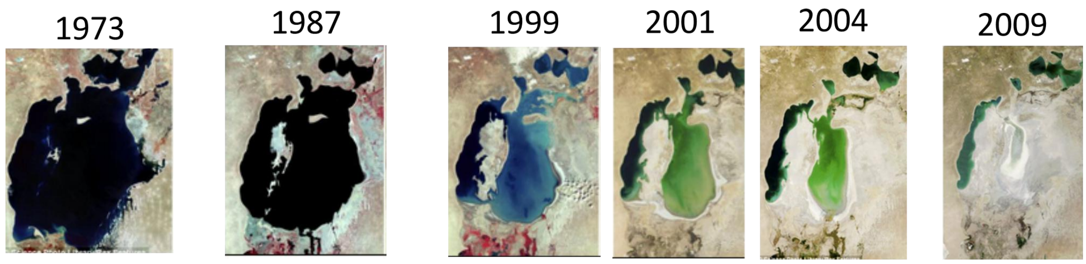
As described in Chapter 3, the study area, which is located on the east side of the Aral Sea in Kazakhstan, the Aral region, has experienced one of the most serious land degradation and desertification in the world since the 1950s. This area has a tragic history of extensive exploitation of natural resources, which has irreversibly destroyed the local ecosystem. The burden of environmental destruction in the latter half of the 20th century was very serious in the Aral region, resulting in a lot of remnants of significant degradation. In recent years, large scale rehabilitation projects have been implemented by the Kazakhstan government and international organizations. In the next chapter, we will outline the two major negative heritages of environmental destruction that the target area has suffered.

## 1.2. Historical background

Forest resource management in the Aral region is subject to the challenges of environmental conservation and life security. Traditionally, the saxaul species has been closely related to local human activities as fuel and feed for livestock. Black saxaul (*Haloxylon aphyllum*) distributing in the Aral region was traditionally used as the main fuel material. Although there is little life-history research conducted in this region, some local residents said that they had used only black saxaul for any heating purposes like cooking, boiling water, making steam for *banya* (a steam sauna for bath), and house heating during Soviet Union era (personal communications with the residents of Karateren district, Qyzylorda province). However, it is currently isolated from the residents. Instead, it is actively used for planting under environmental protection policy. The circumstances leading to the current situation are attributed to the following environmental destruction histories.

The first is known as the 'Aral Sea crisis'. The Aral Sea was previously the fourth largest inland lake in the world by area until the 1960s. Since water level observation began in 1911 a stable sea water level had been maintained by a balance between river inflow and evaporation until 1960 (Micklin, 1991; Bortnik, 1996; Micklin, 2006). However, a system of large-scale and inefficient irrigated agriculture was implemented in 1940s by the Soviet Union in the upper basin of the Syr Daria and Amu Daria Rivers (Spoor, 1998). As these rivers provided much of the water to the lake, depletion of the water supply has led to catastrophic shrinking of the Aral Sea (Micklin, 2004). To promote crop and cotton cultivation in the upper basins of the rivers, depletion of the Aral Sea was considered an inevitable sacrifice (Figure 1). The worst anthropogenic disaster in the twentieth century has left an enormous problem in terms of environmental and socio-ecological issues for future generations. The human-made Aralkum desert formed from the desiccated sea bed has become the main source of saline dust storms (Breckle *et al*., 2012; Wucherer *et al*., 2005), although there is room for discussion to scientifically prove the exact extent of damage in the region (Martius and Lamers, 2016). Severe sand storms with salt and large amounts of moving sand have caused suffering for local people. A massive amount of moving sand surged the neighbor villages. Respiratory illnesses, throat and esophageal cancer, and other health problems caused by salt and dust from the Aralkum desert were reported by several studies (Micklin, 1991; Micklin, 2007, UNEP, 2014).

Furthermore, the salt-dust storms transported a lot of salts to the adjacent crop lands in Kazakhstan and Uzbekistan leading to soil degradation (Spivak *et al*., 2011; Breckle and Geldyeva, 2012). The Aral Sea crisis also brought serious damage to the fishing industry, the local main industry. Many villages along the coast and on local islands were abandoned due to the disappearance of fish species and a collapse of commercial activity (Micklin, 1988). According to a long period of metrological monitoring reported by several Russian-speaking scholars, a significant climate change caused by the river discharge into the Aral Sea was detected in the Aral Sea region (Gaybullaev *et al*., 2012; Zhou *et al*., 2015). The desiccation of the Aral Sea caused an increase in air temperature in summer and a decrease in winter, and a decline of mean annual humidity. The higher air temperature causes an increase in evaporation, and further increase in aridity may lead to another evaporation (Zhou *et al.*, 2015).




(photos: NASA Earth Observatory)

Figure 1. Shrinking Aral Sea

The second is the excessive logging of saxaul that occurred in the 1990s after the Soviet Union era. The collapse of the Soviet Union in 1991 led to the serious decline of the economy and the administrative governance. Owing to the absence of administrators during the early 1990s, political control of the management of regional forests was lost. A large amount of illegal logging for commercial purpose must have been overlooked. However, no detailed records of the damage was left. The collapse of overall planning of land resources in pasture might have caused over-grazing close to villages. Furthermore, demand for firewood might have sharply increased following the collapse of the coal and gas distribution system as well as the increased price of such fuels and transportation (personal communication with residents of Karateren district and staff in the governmental forest office at Kamystybas, Aral region). Massive deforestation in the 1990s led to the depletion and endangerment of black saxaul, which was threatened with extinction (Breckle *et al.*, 2012; Sehring, 2012). According to a report, the forest, which totaled 42,000 ha in the Soviet era has been reduced to 1,000 ha (Sehring, 2012). The decline of the economy and the social turmoil following the collapse of the Soviet Union are behind the excessive logging occurred in 1990s. Because expansion of vegetation is limited by an extreme arid climate (Dimeyeva, 2007), biomass is easily endangered by external pressures. Thus, effective governance relating to the consumption of fuelwood is paramount in this region. However, there have been few studies conducted on fuelwood consumption and forest management at the local community level in recent decades.

## 1.3. Objectives

Based on the issues mentioned above, regarding the regional forests as an important source of ecosystem maintenance, we would like to equally position the two elements of wood resource protection and security of livelihood within sustainable resource management. Therefore, to practice this from a scientific standpoint in the target area, social surveys were conducted with residents and with the authorities, and based on them, provided a possible way planned reforestation from the technical aspect.

Specifically, the task to be addressed in the first step is to grasp the current situation of the use of alternative fuel timber and Tamarisk logging sites, and this was clarified by questionnaires and interviews following a review of political measures and issues in this region. To compensate for the deficiency associated with the regulation of wood logging, most of the demand for fuel materials in the region has been covered by logging of Tamarisk, but evaluation at the consumption level has not been made. In order to examine the governors' risk management and the perspectives on regional consumption of wood, we further interviewed the district's *akimat* (political leader of a district) and the forestry department of the Aral region in the subordinate organization of the Ministry of Agriculture about logging management. This work is described in detail in Chapter 3.

The balance of supply and demand has been overlooked under the current protection policy. This research proposes that resource utilization and environmental protection be considered as complementary elements. However, as a practical matter, the region has little capacity for wood supply because the reforestation projects conducted in this region, aiming at recovering the ecosystem and benefit return to local people, have not succeeded in increasing the supply source. We tried to present practically useful indicators in the selection of reforestation sites by soil scientific approach. This work is described in detail in Chapter 4.

## 1.4. References


Antonia Eastwood, Georgy Lazkov and Adrian Newton (2009) The Red List of Trees of Central Asia, *Fauna & Flora International*, Cambridge, UK.

Breckle, S.W. and Geldyeva, G.V. (2012) Dynamics of the Aral Sea in Geological and Historical Times. In Aralkum-a Man-Made Desert, Springer Berlin Heidelberg.13-35. DOI: 10.1007/978-3-642-21117-1_2

Breckle, S.W., Wucherer, W., Dimeyeva, L. A. (2012) Vegetation of the Aralkum, In Aralkum-a Man-Made Desert, Springer Berlin Heidelberg. 127-159. DOI: 10.1007/978-3-642-21117-1_9

Bortnik, V. N. (1996) Changes in the water-level and hydrological balance of the Aral Sea. In The Aral Sea Basin (pp. 25-32). Springer Berlin Heidelberg.

Dimeyeva, L. (2007) Primary Successions on the new Aral Seashore. *Basic and Applied Dryland Research*. 1(1) 1-16. DOI: 10.1127/badr/1/2007/1

Gaybullaev, B., Chen, S-C., Gaybullaev, D. (2012) Changes in water volume of the Aral Sea after 1960. *Applied Water Science* 2, 285- 291.

Martius, C. and Lamers, J.P.A. (2016) Let there be science: Separating environmental misperceptions from reality in the Aral Sea Basin 67-77, In Eric Freedman and Mark Neuzil (eds.) *Environmental Crises in Central Asia: From steppes to seas, from deserts to glaciers*, Earthscan, New York, USA.

Meshkov, V.V., Baizakov S.B., Yeger A.V., Orozumbekov A. (2009) Forest rehabilitation in Kazakhstan. *Keep Asia green*, 4, 83-130.

Micklin, P. (1988) Dessication of the Aral Sea: A water management disaster in the Soviet Union. *Science,* 241(4870), 1170.

Micklin, P. (1991) The Water Management Crisis in Soviet Central Asia. No. 905, The Carl Beck Papers in Russian and East European Studies. Pittsburgh. *The Center for Russian and East European Studies, August*.

Micklin, P. (2004) The Aral Sea crisis. In: Nihoul CJ, Zavialov P, Micklin P (Eds) *Dying and dead seas—Climatic versus anthropic causes.* Springer: Netherlands: 99–123. DOI: 10.1007/978-94-007-0967-6_5

Micklin, P. (2006) The Aral Sea crisis and its future: An assessment in 2006. *Eurasian*

*Geography and Economics*, *47*(5), 546-567.

Micklin P. (2007) The Aral Sea disaster. *Annual Review of Earth and Planetary Science* 35: 47–72. DOI: 10.1146/annurev.earth.35.031306.140120

Sehring, J. (2012) Forests in the context of climate change in Kazakhstan, Discussion Paper, *Zentrum für internationale Entwicklungs- und Umweltforschung,* No. 60. http://hdl.handle.net/10419/74450

Spivak, L., Terechov, A., Vitkovskaya, I., Batyrbayeva M., and Orlovsky L. (2011) Dynamics of Dust Transfer from the Desiccated Aral Sea Bottom Analysed by Remote Sensing, In Aralkum - a Man-Made Desert -The Desiccated Floor of the Aral Sea (Central Asia), pp.97-106

Spoor, M. (1998) The Aral Sea basin crisis: Transition and environment in former soviet Central Asia. *Development and Change*, *29*(3), 409-435.

UNEP Global Environmental Alert Service (GEAS) (2014) The future of the Aral Sea lies in transboundary co–operation, http://na.unep.net/geas/getUNEPPageWithArticleIDScript.php?article_id=108

Wucherer, W., Veste, M.,Herrera Bonilla, O.,Breckle, S.W. (2005) Halophytes as useful tools for rehabilitation of degraded lands and soil protection, In *Proceedings of the first international forum on ecological construction of the Western Beijing*, Beijing.87-94. http://www.desertconsult.de/PDF/62Halopyhten%20as%20tools_Bejing2005.pdf

Zhou, Y., Zhang, L., Fensholt, R., Wang, K., Vitkovskaya, I., & Tian, F. (2015) Climate contributions to vegetation variations in central Asian drylands: Pre-and post-USSR collapse. *Remote Sensing*, *7*(3), 2449-2470.

# Chapter 2

## Description of the study area

## 2.1. Climate and vegetation

The study area is located at the Aral region, the west part of the Qyzylorda oblast, Kazakhstan. According to the Köppen climate classification, this region has a cold desert climate with a big amplitude in the annual temperature. The annual precipitation is between 80–200 mm. The average temperature is 27.2 °C in July with maximum temperature up to 44.8 °C, and -6.6 °C in January with absolute minimum up to -37.9 °C (CAWaterInfo). Except for the period of snow thaw in March, the rate of evaporation exceeds that of precipitation. Consequently, water available for plants is limited and vegetation is scarce. While in March, the largest supply of ground water occurs. However, the frequent frost on the ground also occurs during several days after the snow melting, which damages the plant body.

*Haloxylon aphyllum* dominates or participates in vegetation of the study areas, classified as euxerophytic desert-tree vegetation or Halophta vegetation (Kurochkina, 2015), where most plant species have obtained a tolerance for drought by several strategies. The ecological range of *H. aphyllum* is wide. It grows on lower ground water level, and both on sandy or clay and cobble soils with various level of salinization (Kurochkina, 2015). Another economically important shrub species in the study area is Tamarisk (*Tamarix hispida*), locally called '*zhungel*', which grows on sand with close ground water like the places around tugai. These two species adapt to different habitats in water and soil environment, but the tamarisk-black saxaul association with participation of different perennial saltwort is also observed on solonchak and old-tugai soils.

## 2.2. General of Karateren district

Karateren District (45°58'54" N and 61°02'50" E) is located along the former seashore at the estuary of the Syr Darya River in the Aral region (Figure 2). This district was established approximately 30 years ago by those who had made their living with fishery on the Aral Sea but suffered from the shrinking of the sea and evacuated. There are many fishermen living in the villages working on season at the near lakes and the small Aral Sea, which has recovered to the level of what it was at its full water body (Micklin, 2008). Stock farming of sheep and goats, camel, caw, and horse is also essential for the local economy. Crop cultivation cannot be seen due to unpreferable climate here as described above.

According to the regional statistics in 2015, the population of this district was 1,677, and was distributed across the following villages: Kone Karateren, Zhana konys, Kol zhaga, and Tastak. There were about 240 households located within the central area comprising Zhana konys and Kol zhaga. Kone Karateren and Tastak had 27 households and 35 households, respectively in 2014. Although the total population of the district shows a rapid increase, population movement from Kone Karateren to the other three villages has been continuing.

Regarding the information access condition, most houses are receiving the domestic TV programs, and the regional newspapers. Although infrastructure for the internet access had not been available except for the public work places such as a school, the village office and the medical clinic, remarkable development is occurring (2016-2017). The usage of mobile phones and information inflow will be dramatically spread over the remote residential areas in the Aral region.

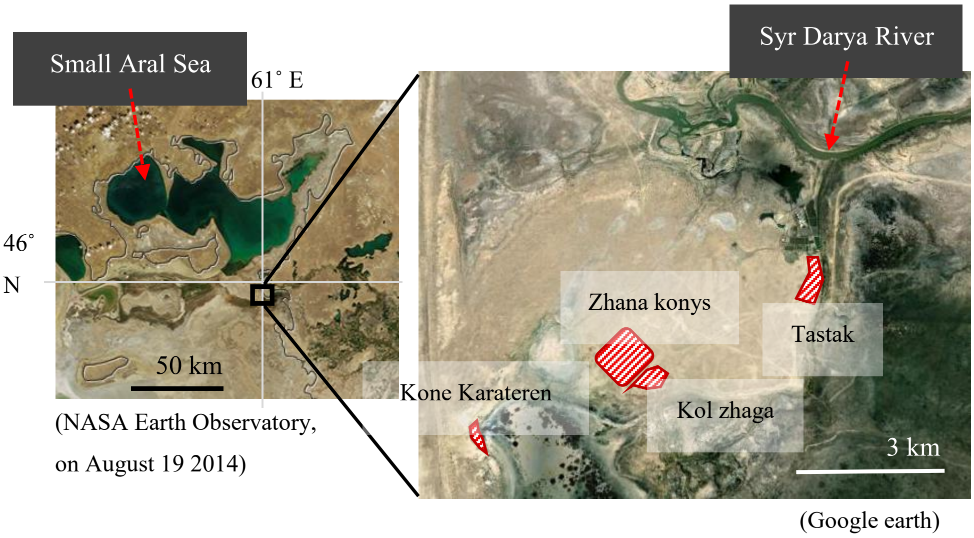



Figure 2. Study site
Gray line in the left map is the coastal line of the full-size lake of the Aral Sea. Karateren district is composed by four villages (diagonal areas).

## 2.3. Description of the black saxaul plot

We conducted the survey at a planting plot for black saxaul adjacent to Zhana konys village of Karateren district. The plot size is 120 × 200 $m^2$. Black saxaul seedlings (1 year old) were planted in 2008 in 15 lanes (200 m long) at 1.5 m intervals. About 1,800 trees are standing with a big variety in height. The study plot has been co-managed by two NGOs from Japan (JRAK) and Kazakhstan (Baitakdala) since 2006 as a test area for planting black saxaul. Irrigation was conducted once a month in the first year but there was no irrigation from the second year.

To avoid the grazing by feeding animals such as goats, sheep, and camels, the plot is enclosed by a fence. Most seedlings were directly planted into the original soil, but some seedlings were planted into the pits of 30 cm deep filled with sandy soils imported.

## 2.4. References

CAWaterInfo. Database of the Aral Sea. http://www.cawater-info.net/aral/data/index_e.htm

Micklin, P. and Nikolay, V. A. (2008) Reclaiming the Aral Sea. *Scientific American* 298(4) 64-71. DOI: 10.1038/scientificamerican0408-64

Kurochkina, L. Y. (2015) Monitoring and mapping of degradation of vegetation formations in the ecosystems of arid Aral Sea region. *Arid Ecosystems*, *5*(4), 201-215. DOI: 10.1134/S207909611504006X

# Chapter 3

# Management of wood resources: A dilemma between conservation and livelihoods

## 3.1. General

### 3.1.1. Forest protection policy in the Aral region

The Kazakh government has enforced several laws concerning the conservation of the saxaul forests in terms of conservation of species and rehabilitation of degraded lands. International organizations have also contributed large funds and undertaken afforestation projects in the Aral Sea basin and the surrounding areas. The figure below summarizes the implemented laws and related projects so far.

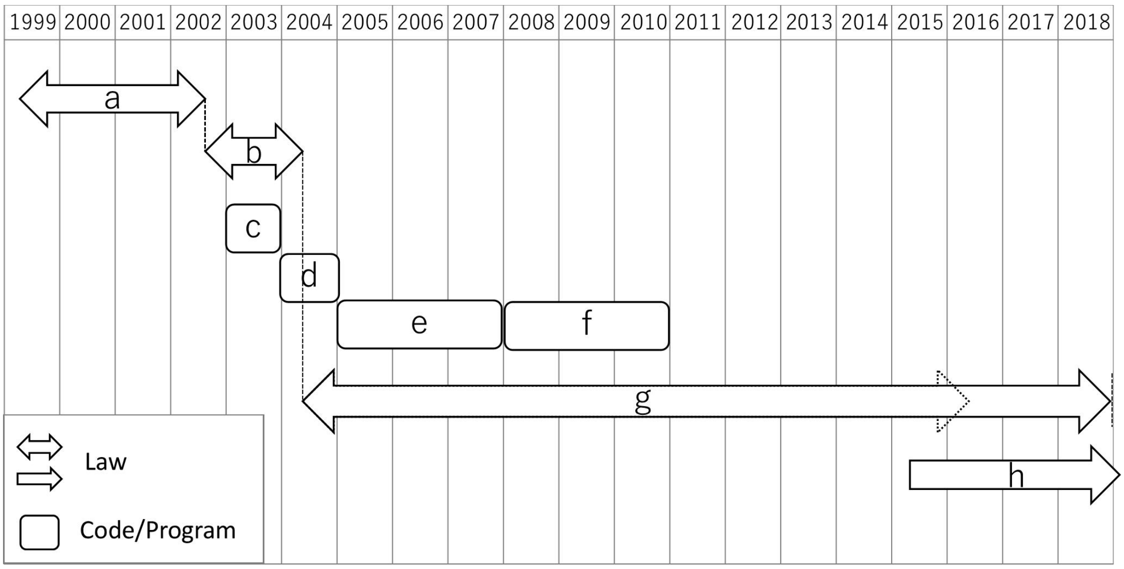



Figure 3. Forest protection policy of Kazakhstan enforced in the Aral region

(Figure 3: a) The law regarding measures concerning the conservation of saxaul (Issued on April 29, 1999, and expired on August 23, 2002) basically prohibited the logging of saxaul at afforestation sites. forest from 1999 to 2002. However, based on the amount of fuel that local residents needed, the law guaranteed that unnecessary saxaul trees could be used for firewood. Further, it was imposed on the oblast governor and relevant agencies of the government to plan and implement activities to protect saxaul forests from illegal logging as soon as possible ([1])

(Figure 3: b) The law regarding the conservation measures of the plantation area of saxaul (Issued on August 23, 2002, and expired on April 23, 2004) continued the content of the previous law. In other words, although it basically prohibited logging of saxaul, it allowed local residents to use unnecessary thinning wood for fuel. In addition to this, an action plan concerning the development of fast grow species to guarantee fuel materials to local residents was imposed upon the oblast governor. ([2])

(Figure 3: c) In 2003, a new Forest Code of the Republic of Kazakhstan was announced. Various regulations established by this Code are noteworthy because they provided the legal foundation for the protection, rehabilitation and improvement of forests in Kazakhstan.

(Figure 3: d) Next, the "Forests of Kazakhstan" Program was approved by the Government in 2004. Its objectives were ensuring the preservation of forests, gradually increasing the area of forested land, and improving the quality of forest stock (Sehring 2012).

(Figure 3: e and f) To more actively stimulate afforestation, the government program "*Zhasyl El*" ("Green Country") was set up in 2005. *Zhasyl El* was composed of two phases, the first phase from 2005 to 2007, and the second from 2008 to 2010 (Sehring 2012).

(Figure 3: g) Following the declaration of the code, regulations on logging were strengthened along with the promotion of protection policy. For example, a law was issued as measures concerning the prohibition of logging for the purpose for use of saxaul from the national forests, which became effective on 23rd April 2004. The law prohibited the felling of saxaul trees at all stages in the planting sites in the national forest of Kazakhstan until December 31, 2018. This measure prohibited the use of thinned wood completely, which previously had been allowed for residents, and instead Tamarisk (*Tamarix hispida*) was suggested as an alternative. The expiry date of this law was set within 2016, but in 2015 another law was issued to continue this content to be effective until December 31 2018. ([3], [4])

(Figure 3: h) In April 2015, a decision was made to prohibit the harvesting of collapsed trees as well as living trees, and logging restrictions were further strengthened. Further, since then measures have been taken to severely punish and increase the penalty those who participate in illegal logging. The protection policy of saxaul has been gradually strengthened like this. ([5],[6])

Although there is a view that, in the long-term, the recovery of the saxaul forest will provide benefits for local residents, planting technology in the last 10 years has remained unable to guarantee this. Currently the recovery of biomass and the rehabilitation of degraded land might be the greatest focus and the ultimate goal of afforestation projects. It is desirable to propose concrete measures on recourse management after planting projects are conducted, that is, a sustainable use of forest resources incorporated into the regional ecosystem cycle. To that end, the first challenge is to precisely grasp the current situation and continue to update the information at the consumer level.

### 3.1.2. Challenges - Authority and Sustainability of alternative measures

According to Antonia *et al.* (2009), the vulnerability of forests in central Asia derives from a lack of alternative energy sources and the lack of institutional capacity to protect and regulate forests despite a high dependency on forests that provide firewood and timber. In the case of Kazakhstan, the Forest and Hunting Committee (FHC), the subordinate organization of the Ministry of Agriculture, is an upper-level organization that manages the forests and protected areas. In 2003, the authority of 81% forest management functions was delegated from the central FHC to the local authorities (*akimat*: political leader of a local district), financed by the provinces. Seventeen per cent of the national forest remains under the direct control of the FHC. Because of a decentralized separated authority system, sufficient levels of management are not achieved owing to a shortage of funds in the provincial governments. Further, the priority that the provinces can attach to forest preservation is relatively low because the *akimats* are responsible for the forest management enterprises. Additionally, there are so-called “territorial inspections” over the provinces. Therefore, the functions of management and control of forests are separated. Such an administrative splitting is considered a hindrance to consistent policy making.

About 15 years have elapsed since the use of black saxaul was prohibited by law and use shifted to Tamarisk as an alternative. Under the vulnerable situation where the local demand for fuel wood is dependent on the only tree species Tamarisk, which is in trade-off relation with protection of black saxaul, even environmental impact assessment on this system has not been made. ‘Will it be possible to maintain a good balance between regional demand and supply in the ecosystem?’ To answer this question, a direct approach would be to know whether the capacity of natural supply, the biomass of Tamarisk, can continuously cover the demand. However, a lack of regional capacity to monitor and conduct forest inventories since the collapse of the Soviet Union has led to little official information on the actual situation of the forests, leading to unreliability of the official data provided. In addition, as is mentioned above, the authority of land ownership depends on districts with different local rules, which obscures the actual land use. Due to such difficulties existing in the region, it is a distant approach to grasp the capacity of natural supply. One possible way is to assess the information about biomass collected from the local residents, who have accessed to the logging places every season. Therefore, in the first instance, the actual reality of wood consumption and local demand must be clarified to implement effective risk management system and political decision making at the local level.

### 3.1.3. Focus of the field survey

To make a progress in discussion on the benefit return to local community from reforestation activities in a context of forest management, understanding the situation regarding the consumption of fuel resources is essential. In this chapter, the residents' attitudes and opinions toward two valuable tree species, black saxaul (*Haloxylon aphyllum*) and tamarisk (*Tamarix hispida*), was focused. Both are economically and environmentally important trees in the Aral region. Here, three main concerns can be refereed regarding the regional forest management. The first one is a poor official information necessary for the analysis and offering toward forest management despite the importance of wood resources in the livelihood. The second is the dependence on a single wooden species, tamarisk, under the population increase in the region. The third one is the invisible preferences to black saxaul as a fuel recognized by the residents under the restriction of cutting. Under the rapid change in society, these hidden facts are potentially significant risks that could endanger the sustainability and disturb the appropriate decision making on the regional forest management.

An understanding of local people's criteria for evaluating fuelwood, their predicted marketing activities, and their attitudes toward management policies would, therefore, contribute important new insights for future decision making. This study, firstly, shed light on the situation regarding the consumption of these resources and to determine what countermeasures should be taken by local authorities. The social survey research was composed of the preliminary survey and the following main survey. In this chapter, the results of preliminary questionnaire survey will be shown in the former because the questionnaire form used in the main survey was designed based on it. Populations of these two surveys were independent. All the information collected in questionnaires and interviews shown in this thesis were permitted to be open by respondents and interviewers.

## 3.2. Materials and methods

### 3.2.1. Data collection

Preliminary survey was conducted in Karateren District from September 18th to October 19th in 2014. Respondents were all aged above 20 years. Although households were randomly surveyed, female respondents exceeded male to collect informative answers about fuel woods, considering that female usually takes care of a process of fire-making in households. One questionnaire was completed per household.

Following a preliminary survey, a main questionnaire-based survey was conducted in Karateren District from September 1 to September 18, 2015. Households were randomly surveyed and respondents were all aged above 20 years. One questionnaire was completed per household, and more than 50% of households in each village within the district were covered. The design of the questionnaire was based on feedback obtained from key informant interviews conducted during the preliminary survey

(Kumar,1989; Marshall, 1996; Cardoso *et al*., 2005). During the questionnaire completion process, open-ended interviews were also carried out with some of the respondents.

A semi-structured interview was held with the district head in July 2014, and again in September 2015, to verify the current population trend and the history of the district. To investigate the logging system applied in the region, a further semi-structured interview was conducted with the director of the forest office on October 12, 2015 at the governmental forest office at Kamystybas, which regulates the flora and fauna of the Aral region. Permission was obtained in advance to record the entire interview.

The purpose of this study was explained to respondents in advance. We further assured respondents that their names would not be disclosed and that the collected information would only be used for academic purposes. The questionnaires and interviews were conducted in the Kazakh language, which is the main language in the region. The collected data were translated into English after completing the survey.

### 3.2.2. Preliminary survey

### 3.2.2.1. Impression for reforestation of black saxaul

To clarify the residents' evaluation for reforestation activities implemented in the Aral region, a question; 'Do you agree or disagree with saxaul planting in the region?' was asked, followed by a question about the reason in free description. The reasons answered in free description were categorized into four classes; 'to prevent sand moving', 'to prevent dispersing of dust and salt', 'for greening' and 'other'.

### 3.2.2.2. Comparison between tamarisk and black saxaul

To investigate how people considered black saxaul as fuel in comparison of tamarisk, which is allowed to use currently, a question; ‘Which do you think is better as fuel, tamarisk or black saxaul?’ was asked, followed by a question about the reason in free description.

### 3.2.2.3. Opinion on future use of black saxaul

Because cutting black saxaul is prohibited in the region, the topic of its use as fuel was expected to be sensitive for the residents. Therefore, it was rather necessary to correctly understand how to treat this topic in the main survey and how they considered the restriction on black saxaul logging. To investigate the people's response and opinions when asked about the future use of black saxaul for fuel, a question; 'Do you want to use saxaul fuel in the future?' was asked, followed by a question about the reason in free description.

### 3.2.3. Main survey

#### 3.2.3.1. Fuel consumption

Current levels of fuel consumption were elicited through questionnaires and observation. A truckload comprised the unit for measuring the annual consumption of fuelwood and coal, and monthly consumption of gas was measured according to the number of bottles consumed, as reported by respondents. The standard volumes of a truckload or gas bottle were investigated and calculated during the preliminary survey. Correlations between family size and annual fuel consumption were determined through the application of Spearman's rank correlation analysis (Sigma Plot 12.5, Systat Software Inc., CA, USA).

#### 3.2.3.2. Residents' evaluations of black saxaul and tamarisk based on their properties and prices

Seven properties for evaluating black saxaul and tamarisk were identified during the preliminary survey to clarify respondents' perceptions of their fuelwood quality. Beneficial properties indicating their quality were: easy to snap, easy to carry, easy to catch fire, strong fire, long-lasting fire, little smoke, and little ash. A five-point Likert scale, ranging from strongly disagree (1) to totally agree (5) was used for questionnaire responses. The Mann-Whitney U test (Sigma Plot 12.5, Systat Software Inc., CA, USA) was performed to compare each of the properties of two fuelwood species, black saxaul and tamarisk.

In addition to their quality, the prices of two types of fuelwood were also evaluated. Respondents noted what they considered to be a reasonable price for a truckload of black saxaul wood.

#### 3.2.3.3. Intention to use black saxaul as fuel

To investigate the intention of respondents to use black saxaul, they were asked whether they would use black saxaul if the logging restriction was lifted, providing a "yes" or "no" response. They subsequently evaluated several items, providing reasons for their affirmative or negative answers, according to a five-point Likert scale, ranging from strongly disagree (1) to totally agree (5). These items were set based on the residents' opinions collected by free descriptions during the preliminary survey.

#### 3.2.3.4. Opinions about the black saxaul logging restriction

Five items were used to evaluate residents' opinions regarding the restriction on cutting black saxaul. A five-point Likert scale was used for residents' responses, ranging from strongly disagree (1) to totally agree (5). These items were derived from the collated opinions of residents collected using an open-ended questionnaire during the preliminary survey.

#### 3.2.3.5. Residents' and governors' perceptions of wood biomass

To investigate residents' perceptions of the region's timber biomass, they were asked to choose one out of five options relating to the amount of biomass: very large, large, normal, small, and very small. Qualitative data on this topic was also obtained through interviews conducted with residents and with the director of the forest office.

## 3.3. Results

### 3.3.1. Description of the respondents

Table 1 presents a profile of respondents who participated in each questionnaire-based survey. Based on random house visits, 162 (54% coverage) samples in the preliminary survey and 192 (64% coverage) samples in the main survey were collected.

Table 1 Component of respondents

| | | Preliminary | Main |
|---|---|---|---|
| Total | | 162 | 192 |
| Sex | | | |
| | female | 113 (69.8%) | 90 (46.9%) |
| | male | 49 (30.2%) | 102 (53.1%) |
| Age | | | |
| | 20s | 24 (14.8%) | 50 (26.2%) |
| | 30s | 41 (25.3%) | 56 (29.3%) |
| | 40s | 41 (25.3%) | 35 (18.3%) |
| | 50s | 27 (16.7%) | 31 (16.2%) |
| | over 60s | 25 (15.4%) | 19 (9.9%) |
| | N.A. | 4 (2.5%) | 1 (0.5%) |

Table shows the component of respondents in two questionnaire surveys. N.A.: not answered

### 3.3.2. Preliminary survey

### 3.3.2.1. Impression for reforestation of black saxaul

Regarding the reforestation activity implemented in the region, 97% agreed (n=152). People who answered affirmatively provided the reasons to be categorized into four items: (a) to prevent sand moving (62%), (b) to prevent dispersing of dust and salt (20%), (c) for greening (7%), and (d) other (11%) including 'to contribute the green policy', 'to make the air clean', 'for future of the village' and so on (Figure 4).

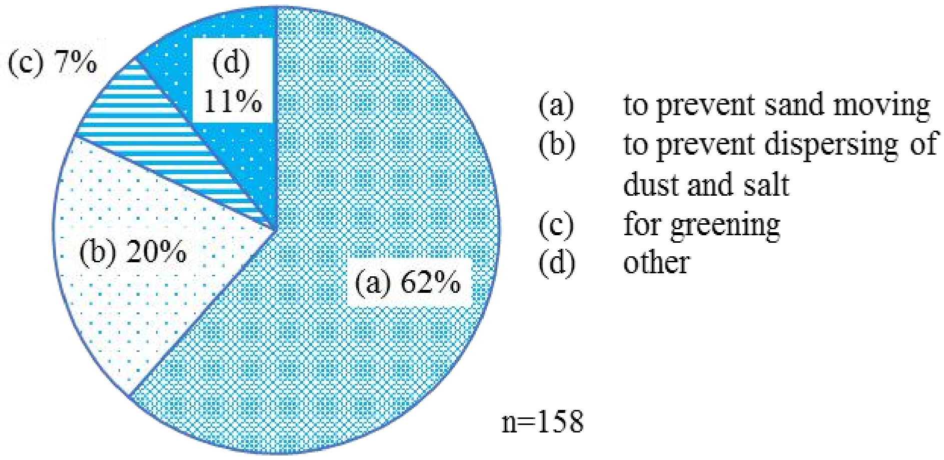



Figure 4. Reasons for affirmative opinion to black saxaul planting

### 3.3.2.2. Comparison between tamarisk and black saxaul

When asked whether they think better as fuel, black saxaul or tamarisk, 60% of respondents (n = 158) answered 'Tamarisk', 23% answered 'Saxaul' and 17% answered 'Both'. Respondents who answered 'Tamarisk' provided the reasons to be categorized into the following seven items: (a) restriction on saxaul cutting (20.6%), (b) awareness of saxaul conservation (7.4%) (c) used to use tamarisk (27.9%), (d) easy to catch fire (20.6%), (e)big biomass of tamarisk (7.4%), (f) heating power (5.9%), and (g) other (10.3%). On the other hand, respondents who answered 'Saxaul' provided the reasons to be categorized into the following two items: (a) heating power (92%) and (b)other (8%) (Figure 5).

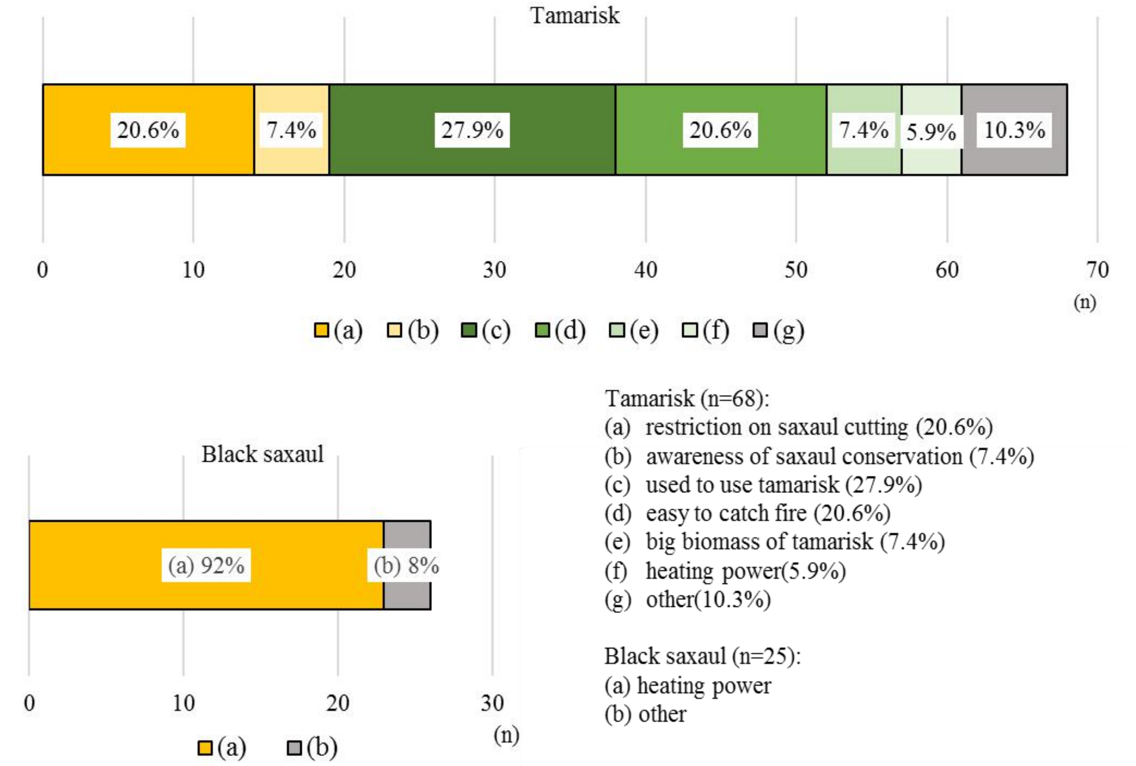



Figure 5. Distributions of evaluation in each reason for 'Tamarisk' or 'Saxaul'

## 3.3.2.3. Opinion on future use of black saxaul

When asked whether they want to use black saxaul fuel in the future, 60% of respondents (n = 161) answered affirmatively, 40% answered that they would not use. All the respondents who answered affirmatively provided the good fuel quality of black saxaul including heating power and long-lasting fire. Also 38% of them added their concerns for the restriction and biomass of black saxaul. Respondents who answered that they would not use black saxaul in the future, also, provided the reasons concerning the restriction (68%) and biomass of black saxaul (14%), and other pro-environmental opinions (13%) (Figure 6).

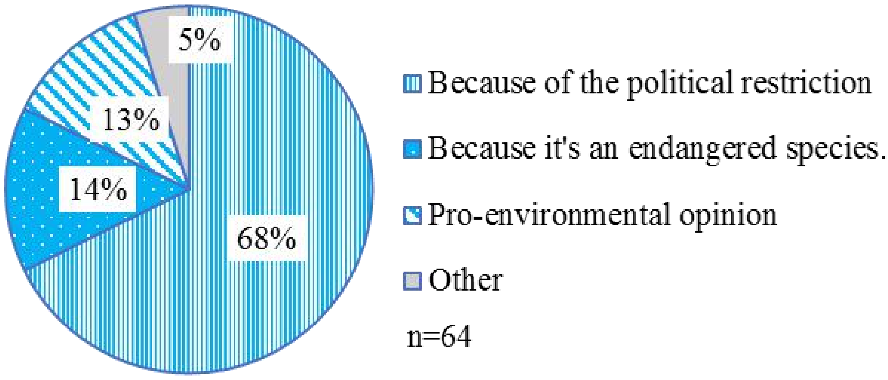



Figure 6. Rate distributions of evaluation in reason for ‘No, I will not use black saxaul in the future.’

### 3.3.3. Main survey

#### 3.3.3.1. Fuelwood consumption

The logging system applied in the Aral region is politically regulated. Under the regulation of the local forest office, residents of Karateren District are permitted to cut three plant species. These species are *Tamarix hispida* (known in English as tamarisk and locally as *zhungel*), *Calligonum leucocladum* (known locally as *zhuzgun*), and *Halostachys caspica* (known locally as *qarabarak*) (Gintzburger *et al.*, 2003). However, based on our observations and on interviews held with residents, tamarisk wood was almost exclusively collected. The logging site is annually decided jointly by the forest office and the district head. Each household is required to get the certification for cutting trees from the forest office, and may be required to pay tax depending on the amount of wood it needs. Households can subsequently cut trees themselves at the specified sites after registering a rented truck at the forest office.

The factors such as size of the accommodation and number of rooms and stoves were eliminated for the statistical analysis through the preliminary survey because no distribution was found in number of stoves in each household. Presence of sauna was also excluded from the analysis because the total amount of wood consumption among the owners of saunas and the other showed no difference. Necessary annual amount of woods for a sauna was extremely small so that the owners did not secure wood but managed within the collected amount for house heating. In the heating system, in most cases, a stove was equipped in one main room, where two adjacent rooms were warmed at the same time by heat going through inside of the wall.

As shown in Table 2, the annual average consumption of tamarisk per household was 13.1 ± 4.8 $m^3$ (± = sd). The price of tamarisk ranged from 8,000 to 12,000 tenge (i.e. 32 – 48 USD) per truckload (about 6 $m^3$). This wood was used to heat houses from the middle of October to early April and was also sometimes burned for boiling water. Some households, which owned saunas, consumed a greater quantity of wood used for heating and boiling water once every week or two weeks. A negative correlation ($r = -0.193$, $p < 0.05$) was found between tamarisk and coal, indicating that these materials were used as alternative sources of fuel for house heating. Family size showed a positive correlation with gas consumption ($r = 0.232$, $p < 0.01$), indicating that the amount of fuel used for cooking depended on the number of household members.

Table 2
Annual fuel consumption and correlation among consumption and family size

| | Tamarisk | Coal | Gas |
|---|---|---|---|
| | n = 191 | n = 191 | n = 191 |
| Price | 32-48 USD/truck (≒6m$^3$) | 71 USD/t | 6.5 USD/50L<br>3.2 USD/27L |
| Annual consumption (Average ±sd) | 13.1±4.8 m$^3$ | 2.3±1.4 t | 574±240L |
| Family size | -0.011 | 0.099 | 0.232** |
| Tamarisk | | -0.193* | 0.16 |
| Coal | | | 0.056 |

1USD = 252 Tenge (average on Sep. 1-18, 2015)
* $P < 0.05$, ** $P < 0.01$

### 3.3.3.2. Population dynamics

Statistics available for the district indicated that its population was 1,702 in 2014. During an interview, the head of Karateren District observed that the population had been increasing over a period of a decade and was projected to soon reach 2,500, based on an annual increase of 14 to 15 households. Although limited census data was obtained, as shown in Table 3, these data supported this finding of a rapid population increase. Moreover, during our study, we observed several new houses, in the process of being constructed, located along the peripheries of Zhana konys and Kol zhaga (the central area of the district).

Table 3
Population of the Karateren district

| Year | Total |
|---|---|
| 2000 | 574 |
| 2001 | 584 |
| ... | ... |
| 2011 | 1657 |
| ... | ... |
| 2014 | 1702 |

Data source: statics service of the Aral region

### 3.3.3.3. Residents' evaluations of black saxaul and tamarisk based on their properties and prices

A comparative analysis of local residents' assessments of the quality of fuel obtained from black saxaul and tamarisk wood revealed that black saxaul was highly valued for its fuelwood quality (Table 4). The results of the Mann-Whitney U test showed that there were no significant differences between tamarisk and black saxaul relating to their properties of being easy to snap, and catching fire easily. A significant difference was found relating to the property of being easy to carry, indicating that prior to burning, tamarisk was easier to handle than black saxaul. On the other hand, respondents evaluated black saxaul much more highly than tamarisk in terms of the following properties: a strong fire, a long-lasting fire, and production of little smoke and little ash ($p < 0.01$).

Table 4
Comparison of fuel quality between saxaul and tamarisk

| | Saxaul (n = 178) | Tamarisk (n = 178) | $U$ |
|---|---|---|---|
| | mean rank | mean rank | |
| easy to snap off | 3 | 3 | 14151 |
| easy to carry | 3 | 4 | 11936* |
| easy to catch fire | 4 | 4 | 15271 |
| strong power of fire | 5 | 3 | 4286* |
| long-lasting fire | 5 | 3 | 2783* |
| little smog | 3.5 | 3 | 8218* |
| little ash | 3 | 2 | 9734* |

Mann-Whitney U test * $p < 0.01$

Tamarisk was preferred in 'easy to carry, while saxaul was preferred in the process after catching fire; strong power of fire, long-lasting fire, little smog and little ash.

According to staff at the local forest office, the standard volume of wood that can be loaded on to a truck is about 6 $m^3$. At the time of the study, the cost of tamarisk ranged between 8,000 and 13,000 tenge (i.e. 32 – 52 USD) for a truckload. Fig. 5 shows the maximum price that the respondents were willing to pay for a truckload of black saxaul wood, which ranged from 18,000 to 23,000 tenge (i.e. 71 – 91 USD), being double or treble the price that they were willing to pay for tamarisk wood. A total of 82% of the respondents (n = 171) were willing to pay a higher price for black saxaul wood than for tamarisk wood.

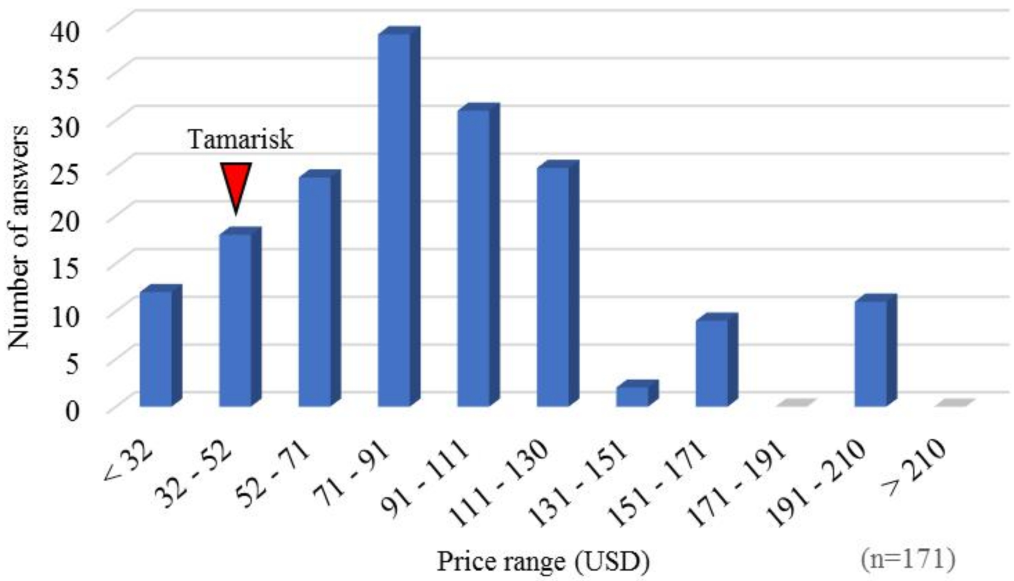



Figure 7. Hypothetical price of a truck of black saxaul

The number of respondents who answered the each range of price for a truck of saxaul were counted. The red arrow is the actual price range of a truck of tamarisk (6m3). The unit is USD calculated by the average rate of Kazakhstan currency tenge to USD during survey period. (1USD = 252 tenge)

### 3.3.3.4. Intention to use black saxaul as fuelwood

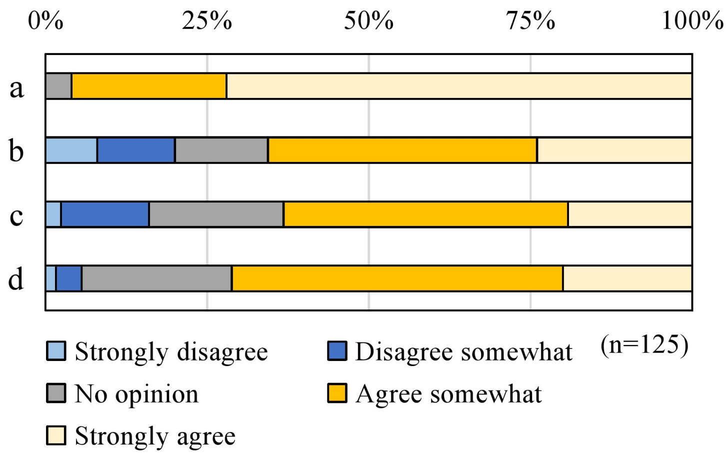



Figure 8a. Rate distributions of evaluation in each reason for ‘Yes, I will use’
68% of respondents (n = 192) answered affirmatively when asked whether they would use black saxaul if the restriction was lifted. Items: a. Fire power is strong; b. Saxaul can be sold; c. Saxaul is cheaper than coal; d. I’m worried of the decrease of tamarisk

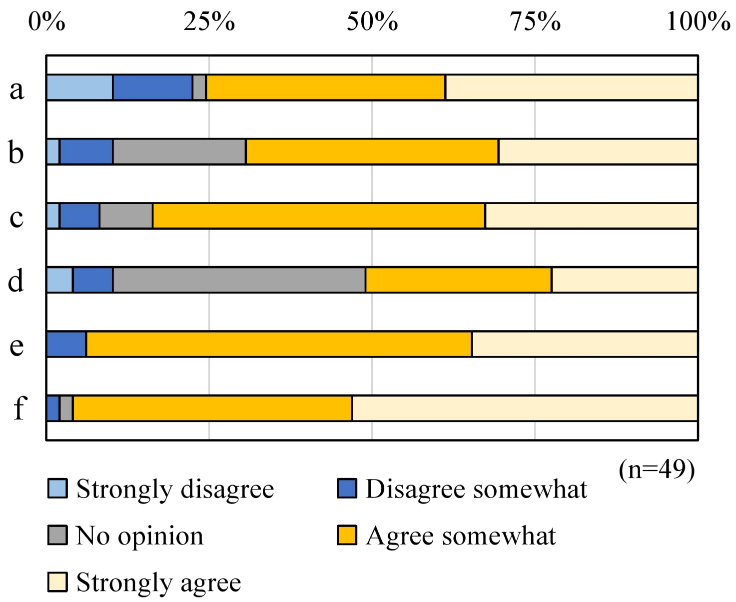



Figure 8b. The evaluation of the reason items for ‘No, I won’t use’
29% of respondents (n = 192) answered negatively when asked whether they would use black saxaul if the restriction was lifted. Items: a. saxaul is not needed for fuel; b. saxaul is expensive; c. Tamarisk should be used instead of saxaul; d. The number of tamarisk is large; e. I’m worried of the decrease of saxaul; f. Saxaul should be used for plantation

When asked whether they would use black saxaul if the restriction was lifted, 68% of respondents (n = 192) answered affirmatively and 29% stated that they would not use this wood. Respondents who answered affirmatively were provided with the following four explanatory items: (a) Saxaul gives a strong fire, (b) Saxaul can be sold, (c) Saxaul is cheaper than coal, and (d) I am worried about the decrease in tamarisk trees (Figure 8a). For all of the items, the level of agreement (agree somewhat and strongly agree) was higher than the level of disagreement (disagree somewhat and strongly disagree). Agreement of respondents was highest (96%) for item (a), ranging between 63% and 71% for the other items.

Respondents who stated that they would not use black saxaul expressed their level of agreement with six explanatory items. These items were: (a) Saxaul is not needed for fuel, (b) Saxaul is expensive, (c) Tamarisk should be used instead of saxaul, (d) Tamarisk is abundant, (e) I am worried about the decrease in saxaul trees, and (f) Saxaul should be used for plantation. Although the level of agreement of respondents was significantly higher than the level of disagreement for all of the items, the ratio of agreement to disagreement was particularly high for items (c) (84%), (e) (94%), and (f) (96%), which referred to the region's environment (Figure 8b). Among these explanatory items, (d) evidenced the lowest level of agreement (51%) and the highest percentage of respondents who did not have an opinion on this topic (39%). The highest ratio of disagreement (22 %) occurred for item (a).

It is noteworthy that both groups of respondents (who would either use or not use black saxaul) expressed concern about the biomass of tamarisk in the region during the preliminary survey (3.2.3. Opinion on future use of black saxaul). This question was investigated further, and in more detail, within the questionnaire used for the main survey, as shown in Figures 8. Among the items associated with the use of black saxaul, the second highest level of agreement (71%) occurred for (d) (I am worried about the decrease in tamarisk trees) (Figure 8a). Among the items associated with respondents' non-use of black saxaul, the lowest level of agreement (51%) occurred for (d) (Tamarisk is abundant) (Figure 8b).

### 3.3.3.5. Opinions about the black saxaul logging restriction

Figure 9 depicts residents' opinions regarding the current restriction on the logging of black saxaul trees. Among the explanatory items (a–e), two items, namely, (a) (The lack of availability of saxaul causes inconvenience) and (e) (I want the restriction to be lifted) were critical of the logging restriction. Conversely, three items, namely (b) (The restriction of saxaul is necessary), (c) (Tamarisk can be used as a substitute for saxaul), and (d) (Coal can be used as a substitute for saxaul) were supportive of the restriction.

Among all of the items, (a) evidenced the highest level of disagreement (disagree and strongly disagree) at 36% and the lowest level of agreement (agree and strongly agree) at 48%. The second highest level of disagreement (21%) was obtained for item (e). However, the ratio of agreement for this item was also the second highest (69%) among the items.

The ratios of disagreement for items (b), (c), and (d) were small, ranging between 9% and 14%, and the ratio of agreement was high, ranging between 58% and 72%. The highest level of agreement (72%) was found for (b). Moreover, many of the respondents took a long time to answer this question and were reluctant to give a clear answer (agree or disagree) for items (c) and (d), resulting in the highest ratios of "no opinion" for these items (30% and 24% respectively).

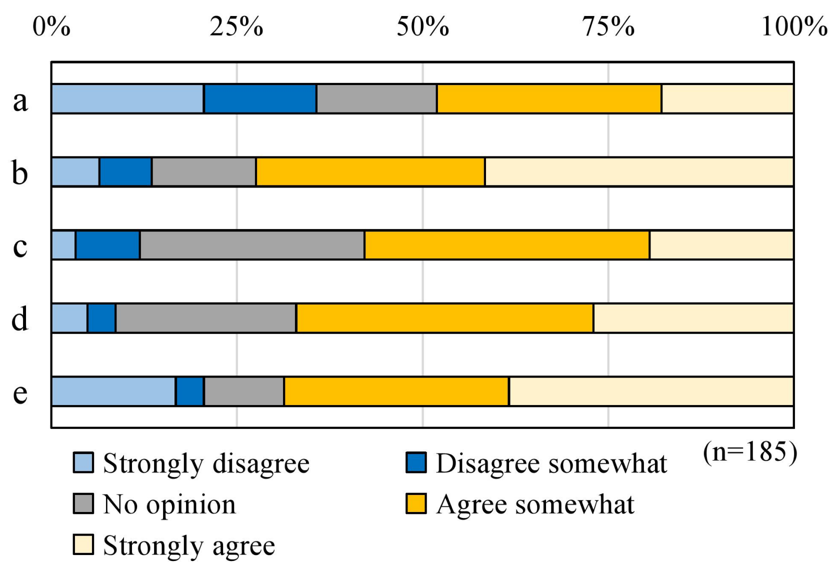



Figure 9. Residents' opinions toward the restriction of logging black saxaul
Items: a. It is uncomfortable that saxaul is not available.; b. The restriction of saxaul is important.; c. Tamarisk can substitute for saxaul.; d. Coal can substitute for saxaul.; e. I want the restriction to be lifted.

## 3.3.3.6. Perceptions of tamarisk biomass

When queried about their perceptions regarding tamarisk biomass, 59% of the respondents felt that biomass was "normal" and that there was neither an increase nor a decrease, 24% felt that the amount of biomass was small or very small, and 17% perceived the amount of biomass to be large or very large (Figure 10). During open-ended interviews held with residents, some respondents expressed concern that the number of old trees had decreased recently, and consequently they had no choice but to cut young trees to meet their demands. However, the view of the director of the forest office was that the rule permitting residents to cut only old trees in logging sites was being effectively applied in this region. Moreover, the director suggested that the fast-growing tamarisk supported fuelwood demands in the region.

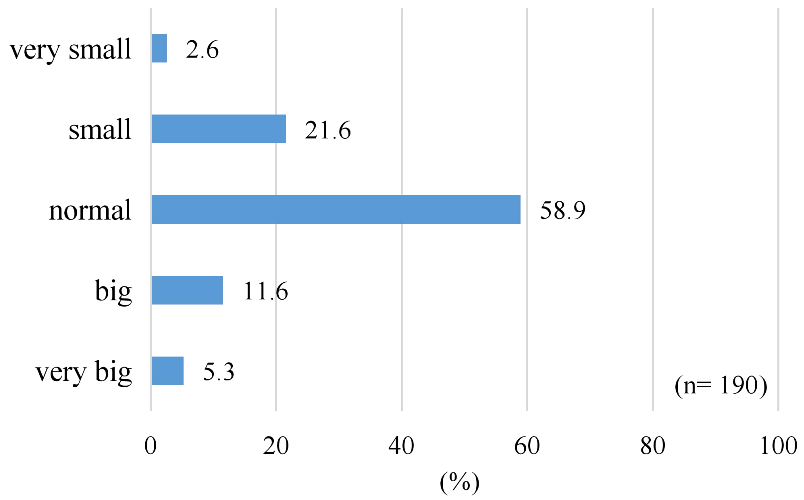



Figure 10. Recognition of the tamarisk biomass

## 3.4. Discussion

### 3.4.1. Fuelwood consumption

Because arid regions are particularly vulnerable to the impacts of human activities, there is a need for carefully designed and implemented forest management in such regions (Cardoso *et al.*, 2015; FAO, 1993; Reynolds *et al.*, 2007). Considering that vegetation is absolutely scarce in the dryland ecosystems, fuelwood is valuable for sustaining people's livelihoods in drylands (Ramos *et al.*, 2008; Hiemstra-van der Horst and Hovorka, 2009; UNEP, 2005). Especially in the remote areas where the energy transport from the outside is inefficient and costive, a sustainable usage of local wooden resources has traditionally been the most preferable way. Therefore, local wood resources under careful management needs to be seriously considered once the balance of ecosystems including local livelihoods is endangered. This is also the case in the Aral region (Meshkov *et al.*, 2009).

Through the observations in preliminary survey, we confirmed that coal and tamarisk are the fuel resources used for the house heating system, and these materials are alternative to each other. This was also statistically supported from the quantitative data collected in the main survey. The results of the study indicated a correlation between the consumption of gas and family size, because gas is used for cooking. However, there was no correlation found between the consumption of tamarisk and coal and family size, because these materials are used for house heating (Table 2). Moreover, the findings revealed that not everybody could afford to buy coal. Further, even among households that purchased coal, the main fuel used was tamarisk wood and not coal. Consequently, whereas gas could replace wood used for cooking, it could not replace wood used for heating houses. This is because the heating system is optimized for wood and coal burning. As a result, the demand for fuelwood will not decline. Rather, given the increase in houses in the district over for the last decade, fuelwood consumption will continue to increase (Table 3).

### 3.4.2. Perceptions of tamarisk biomass

As shown in Fig. 8, residents' perceptions of tamarisk biomass suggest that while the decline of tamarisk has not yet become an urgent issue, the ratio of respondents who considered the amount of tamarisk in the region to be small or very small was higher than the ratio of respondents who considered this quantity to be large or very large. An early indication of a decline in this species was revealed in the concern expressed by some respondents regarding the shortage of old tamarisk trees at logging sites for meeting their requirements. Because young trees have high moisture content, burning them can cause health problems resulting from incomplete combustion (Kandpal *et al.*, 1995; WHO, 2006; de Albuquerque Sgarbi, 2013). Further, low combustion efficiency results in high consumption, which, in turn, leads to increased collection of fuelwood from forests (Miah *et al.*, 2009). The findings on local residents' attitudes and the reasons for these attitudes, which have a bearing on the future use of black saxaul (Figs. 6), also support the conclusion that residents are conscious of the amount of tamarisk biomass, as discussed in section 3.3.3.6. However, the difference in the perceptions of residents and forest office authorities implies that a functional feedback mechanism within the forest governance system is not in place. This gap, which leads to a lack of consideration of potential risks, would make it difficult for authorities to collect critical information about forests in the region and to thereby engage in appropriate decision making (Pagdee *et al.*,2006; Bhattacharya *et al.*, 2010; Gertler *et al.*, 2004).

### 3.4.3. Preference for black saxaul

Despite the evident significance of residents' preference for black saxaul as a fuelwood source, a prohibition on logging this species has been in place over the last decade (Fig. 5 and Table 4). The findings of this study regarding respondents' attitudes toward using black saxaul as a fuelwood source suggest that its high fuelwood quality could be the strongest incentive for its use (Fig. 6a).

### 3.4.4. Environmental consciousness

On the other hand, the respondents' environmental attitude that prioritized conservation of black saxaul above satisfaction with alternative fuelwood resources like tamarisk was a strong deterrent to logging (Fig. 6b). This finding suggests that efforts to educate and inform the community would be effective. Public opinion regarding the black saxaul logging restriction suggests that likely reasons for residents' acceptance of the current situation are that their fuel demands are being met by tamarisk, as well as the high level of environmental consciousness among residents. Many residents are evidently facing a dilemma regarding their environmental awareness and consumption of fuelwood resources. To increase the absolute amount of resources should also be considered by technical improve in planting black saxaul, which has been a challenging issue for a long time in rehabilitation policy in the Aral region. From the perspective of sustainable livelihood, the demand on it will increase as well.

### 3.4.5. Technical improvement

Although its importance has been continuously stated in several assessments and international meetings, benefit return to local residents from saxaul planting projects has not be achieved by any domestic or international reforestation projects so far (World Bank, 2011; FAO 2014). Further challenges of environmental projects are to propose a future resource management after the projects, and to make a technological progress to support the management. Black saxaul fuel was the main heat source for living, which had been traditionally continued until late twentieth century. Technical improvement, therefore, might be urgent to recover the resilience of the ecosystem that provides fuelwood for local residents as originally served, owing to the current high dependence on one species under the arid climate. It is required for both environmental preservation and sustainable resource utilization. However, overall results from the recent decade are not promising with a very low survival rate of seedlings (25%–30%) (Meshkov *et al.*, 2009). Despite their efforts at reforestation, the reasons for low survival have not yet been clarified.

## 3.5. Conclusion

Because tamarisk is the only primary fuelwood species available in the study district, it is likely to become endangered in the future as a result of excessive demand. It is imperative to avoid a potentially critical situation resulting from a severe shortage in fuelwood supplies and land degradation caused by over logging. Although black saxaul has considerable potential for supporting local fuelwood demands, as evidenced by residents' preference for it, reflected in past consumption levels, this species requires careful management. Following a long period of logging restrictions, the current biomass of black saxaul in the region should be assessed. To introduce appropriate risk-based management of forests in this region, we recommend the implementation of an assessment of logging sites and the establishment of a feedback system involving local communities. Moreover, from the perspectives of securing environmental conservation as well as local livelihoods, active political efforts relating, for example, to the use of timber obtained from the thinning, in conjunction with reforestation projects and planting fuelwood species, should be considered.

## 3.6. References

Antonia Eastwood, Georgy Lazkov and Adrian Newton (2009) The Red List of Trees of Central Asia, *Fauna & Flora International*, Cambridge, UK.

Bhattacharya, Prodyut, Lolita Pradhan, and Ganesh Yadav (2010) "Joint forest management in India: Experiences of two decades." *Resources, Conservation and Recycling* 54.8. 469-480. DOI: 10.1016/j.resconrec.2009.10.003

Cardoso, M. B., Ladio, A. H., Dutrus, S. M., Lozada, M. (2015) Preference and calorific value of fuelwood species in rural populations in northwestern Patagonia, *Biomass Bioener*. 81. 514-520. DOI: 10.1016/j.biombioe.2015.08.003

de Albuquerque Sgarbi, F., Simões, A. F., dos Santos, E. M., Salinas, D. T. P. (2013) Fuelwood as an energy source for the commercial cooking sector–An overview analysis focused in the city of São Paulo, Brazil. *Biomass Bioener*. 58. 313-321. DOI: 10.1016/j.biombioe.2013.09.007

FAO (1993) Sustainable development of drylands and combating desertification http://www.fao.org/docrep/v0265e/v0265e00.htm#Contents

FAO (2014) Global forest resources assessment 2015. FAO Forestry paper Rome, Italy. http://www.fao.org/3/a-az250e.pdf

Gertler, Meric S., and David A. Wolfe (2004) Local social knowledge management: Community actors, institutions and multilevel governance in regional foresight exercises, *Futures* 36.1.45-65. DOI: 10.1016/S0016-3287(03)00139-3

Gintzburger G, Toderich KN, Mardonov BK, Mahmudov M. (2003) Rangelands of the arid and semi-arid zones in Uzbekistan. V. Howe and CIRAD Editing and Publication Service, France426.

Hiemstra-van der Horst, G. and Hovorka, A. J. (2009) Fuelwood: The “other” renewable energy source for Africa? *Biomass Bioener.* 33(11) 1605-1616. DOI: 10.1016/j.biombioe.2009.08.007

Kandpal, J. B., Maheshwari, R. C., Kandpal, T. C. (1995) Indoor air pollution from combustion of wood and dung cake and their processed fuels in domestic cookstoves. *Energy conversion and management.* 36(11) 1073-1079.

Kumar, K. (1989) Conducting key informant interviews in developing countries, A.I.D. program design and evaluation methodology report No. 13, USAID, Washington, DC. http://www.alnap.org/pool/files/pnaax226.pdf

Marshall, M. N. (1996) The key informant technique, Family practice 13(1) 92-97. DOI: 10.1093/fampra/13.1.92

Meshkov VV, Baizakov SB, Yeger AV, Orozumbekov A. (2009) Forest rehabilitation in Kazakhstan. *IUFRO World Series* 20(4): 83-130. IUFRO Headquarters, Vienna, Austria.

Miah, M. D., Al Rashid, H., Shin, M. Y. (2009) Wood fuel use in the traditional cooking stoves in the rural floodplain areas of Bangladesh: a socio-environmental perspective, *Biomass Bioener.* 33(1) 70-78. DOI: 10.1016/j.biombioe.2008.04.015

Pagdee, Adcharaporn, Yeon-su Kim, and Peter J. Daugherty (2006) What makes community forest management successful: a meta-study from community forests throughout the world, *Society and Natural Resources* 19.1, 33-52. DOI: 10.1080/08941920500323260

Ramos, M. A., de Medeiros, P. M., de Almeida, A. L. S., Feliciano, A. L. P., de Albuquerque, U. P. (2008) Can wood quality justify local preferences for firewood in an area of caatinga (dryland) vegetation? *Biomass Bioener.* 32(6) 503-509. DOI: 10.1016/j.biombioe.2007.11.010

Reynolds, J. F., Smith, D. M. S., Lambin, E. F., Turner, B. L., Mortimore, M., Batterbury, S. P., Huber-Sannwald, S. P. (2007) Global desertification: building a science for dryland development, *Science* 316(5826) 847-851. DOI: 10.1126/science.1131634.

Sehring, J. (2012) Forests in the context of climate change in Kazakhstan, Discussion Paper, *Zentrum für internationale Entwicklungs- und Umweltforschung,* No. 60. http://hdl.handle.net/10419/74450

UNEP (2005) Dryland Systems. In "Ecosystems and Human Well-being: Current State and Trends". Chapter 22. 623-662.

World Bank (2011) Implementation Status and Results: Kazakhstan Forest Protection &Rehabilitation Project. http://www.worldbank.org/projects/P078301/forest-protection-reforestation-project?lang=en

World Health Organization (WHO) (2006) Fuel for life: household energy and health. WHO, Geneva. http://www.who.int/indoorair/publications/fuelforlife/en/

**Links**


[1] Сексеуіл ормандарын сақтау жөніндегі шаралар туралы
Қазақстан Республикасы Үкіметінің қаулысы 1999 жылғы 29 сәуір N 526.
Күші жойылды - ҚР Үкіметінің 2002.08.23. N 942 қаулысымен. ~P020942
URL: http://adilet.zan.kz/kaz/docs/P990000526_

[2] Қазақстан Республикасында сексеуіл екпелерін сақтау жөніндегі шаралар туралы, Қазақстан Республикасы Үкіметінің қаулысы 2002 жылғы 23 тамыз N 942. Күші жойылды - ҚР Үкіметінің 2004.04.23. N 460 қаулысымен.
URL: http://adilet.zan.kz/kaz/docs/P020000942_

[3] Мемлекеттік орман қоры учаскелеріндегі қылқан жапырақтылар мен сексеуіл екпелерінде басты мақсатта пайдалану үшін ағаш кесуге тыйым салу және оларды сақтау жөніндегі шаралар туралы, Қазақстан Республикасы Үкіметінің 2004 жылғы 23 сәуірдегі N 460 қаулысы. Күші жойылды - Қазақстан Республикасы Үкіметінің 2016 жылғы 30 қаңтардағы № 43 қаулысымен
URL: http://adilet.zan.kz/kaz/docs/P040000460_

[4] Қазақстан Республикасы Ауыл шаруашылығы министрлігінің кейбір мәселелері
Қазақстан Республикасы Үкіметінің 2005 жылғы 6 сәуірдегі N 310 Қаулысы, 376) 'ағаштардың қурау және құрып кету қатері төнген кезде мемлекеттік орман қоры учаскелерінде ағаш кесуге тыйым салу туралы шешім қабылдайды'
URL: http://adilet.zan.kz/kaz/docs/P050000310_#z1240

[5] Мемлекеттік орман қоры учаскелеріндегі сексеуіл екпелерінде ағаш кесуге тыйым салу туралы, Қазақстан Республикасы Ауыл шаруашылығы министрлігінің Орман шаруашылығы және жануарлар дүниесі комитеті төрағасының 2015 жылғы 13 тамыздағы № 211 бұйрығы. Қазақстан Республикасының Әділет министрлігінде 2015 жылғы 14 қыркүйекте № 12057 болып тіркелді
URL: http://adilet.zan.kz/kaz/docs/V1500012057

[6] Арал ауданы Сексеуіл кентінің жергілікті қоғамдастық жиналысының Регламентін бекіту туралы, Қызылорда облысы Арал аудандық мәслихатының 2018 жылғы 23 мамырдағы № 154 шешімі. Қызылорда облысының Әділет департаментінде 2018 жылғы 5 маусымда № 6306 болып тіркелді
URL: http://adilet.zan.kz/kaz/docs/V18LC006306

# Chapter 4

# Soil properties that determine the mortality and growth of *Haloxylon aphyllum*

## 4.1. General

Technical improvement in black saxaul planting is the key to support the regional livelihood as well as rehabilitation on the desiccated seabed and the neighbor areas. It has been considered that black saxaul must be protected and should never be used due to environmental destruction in the latter half of the 20th century. But, in a context of regional wood resources, an alternative species Tamarisk is exposed to a danger after prohibition of using black saxaul, which was the main source of wood fuel.

Increasing the biomass of black saxaul will recover the resilience of the whole ecosystem including the activity of local livelihood. Benefit return to the people from reforestation of black saxaul is not a “byproduct” of projects, but the ultimate goal for the regional ecosystem. In this chapter, a suggestion on current technical issue that can contribute to the appropriate site selection on planting black saxaul is given from the view point of soil science.

Kazakhstan is composed of desert saxaul (*Haloxylon spp.*) shrublands, which are dominant in the deserts of the Aral region. Saxaul-dominated forest makes up 50% of all types of national forests in Kazakhstan (Meshkov *et al.* 2009). Three Haloxylon species, *Haloxylon ammodendron* (C.A. Mey.) Bunge, *H. persicum* Bunge ex Boiss. et Buhse (Chenopodiaceae), and *H. aphyllum*, have been reported, with different distribution areas. Among the Haloxylon species, *H. aphyllum,* is especially dominant, adapted to the saline and clayey arid regions as well as to sandy desert (Herbel *et al*. 1981; Khassanov, Rachimova, and Tadzhiev 1994).

Planting black saxaul on the former sea bed has proved effective in reducing wind velocity and dust transport and in accelerating the growth of vegetation cover (Novitskiy 2012). For homogeneous stand establishment, at many reforestation project sites, strip soil preparation was applied at a depth of 25–27 cm, where the sandy soil was imported. However, the overall results of reforestation were not successful with seedling survival rate of only 25–30% (Meshkov *et al.* 2009). Despite their efforts at reforestation, the reason for low survival has not yet been clarified.

Ecologically, *H. aphyllum* is highly adapted to arid areas. Since the species is always exposed to severe water constraints, a deep pivotal root system is formed, penetrating to depths of 9 to 16 m to reach water (Gintzburger *et al.* 2003). Wei et al. (2007) monitored the growth of saxaul seedlings for six months after planting. They found that in the first three months a rapid growth in the vertical root system occurred that extended to a depth of 100 cm, after which the elongation rate decreased and other parts of the plant, such as shoots and lateral roots, started to grow at a rapid rate. Their results indicated that under favorable conditions, the root of the seedling can reach a subsoil depth of 100 cm in the initial year of planting. Exposure to sub-soil determines the root establishment and the following growth of above ground shoot. Since a standard method of strip soil preparation for planting has long been applied in the Aral Sea region, as mentioned above, it is useful to gather evidence and raise awareness of the importance of the subsoil environment.

The main difficulties for plants in arid regions in accessing water are physical soil impedance and osmotic stress caused by excessive amounts of salts (Dexter 2004). The water acquisition strategy of black saxaul also needs to be considered. Root elongation to the subsoil in the initial year after planting is crucial for root establishment to support the subsequent growth of shoot biomass. The adverse effects on plants arise from several physical and chemical properties of the soil and topographic conditions. The physical properties of the soil and topography are the physical factors controlling the water dynamics in soil. The water dynamics determine the spatial allocation of water-soluble salts. Salts in soil directly cause osmotic stress for plants and also affect the aggregate structure of soil particles. The decline of soil structure may cause poor drainage and the physical impedance of root elongation. Also, several studies have reported that elevation affected soil salinity and was the cause for decrease in crop yields (Funakawa and Kosaki 2007; Li, Shi, and Li 2007; Fan *et al.* 2012; Nguyen, Watanabe, and Funakawa 2014). This may be because topography can change the horizontal direction of water flow.

In this study, we investigated the plant response to these environmental factors to clarify the conditions required for black saxaul seedlings to survive under difficult conditions. Appropriate site selection based on soil assessment is urgently needed to increase the success rate and cost-effective reforestation, leading to the planned forest management in the region. This study will contribute by offering a practical index for site selection for reforestation by black saxaul. Focusing on the subsoil environment for black saxaul trees, we tested the hypothesis that a greater soil depth needs to be considered than has previously been suggested in reforestation projects in the Aral region. To test the hypothesis, this study investigated the following questions: (1) why are current soil preparation treatments not effective, (2) how deep is the critical depth for seedling survival, and (3) which factor(s) affects the growth of black saxaul trees after root establishment?

## 4.2. Materials and Methods

### 4.2.1. Experimental design

To explain the spatially homogenous condition in plant growth, the special distribution of the environmental factors was considered. The factors, which were treated as the explanatory variables included topographic factors such as the relative elevation and the depth of hard layer, and soil physical and chemical properties such as soil texture, ECe (electric conductivity extracted from saturation paste), SAR (sodium adsorption ratio), and Na %. As mentioned above, the plant height was used as the index of plant growth in this study.

In addition to the identification of the factors affecting the growth, the soil condition necessary for the establishment of a planted seedling was investigated by comparing the different patterns of soil profile among the sampling points with different mortality rates.

### 4.2.2. Temperature dynamics in soil

To measure the soil temperature during the year (October 2014- September 2015), the stand-alone temperature sensors (TR51S, T AND D Corporation, Japan) were installed at the depths of 10 cm, 30 cm and 50 cm.

### 4.2.3. Plant height measurement

Because plant height is closely correlated with the biomass in *H. aphyllum* (Buras *et al.* 2012), the height of all the black saxaul trees including dead trees in the plot was measured as the growth index. Plant height (above the shoot) was measured by a ruler from base to top of the tree. In addition, the position of every fifth tree was recorded (356 points) by a GPS receiver (GPS Map 62 s, GARMIN, USA).

### 4.2.4. Topographic factors

The relative elevation and depth of the hard layer were measured at 38 points in the plot (Figure 11). Relative elevation was measured using GNSS receivers (GRS-1, TOPCON, Tokyo, Japan) in static mode, then analyzed by GNSS-Pro software (TOPCON, Inc. Pinnacle Program: version 3. 10, Tokyo, Japan) using random vector analysis.

The depth of the hard layer in the subsoil was defined as the depth at which the auger could not penetrate further due to the physical impedance. To describe the physical features of the layer, soil core samples were taken for the measurement of bulk density and hydraulic conductivity. Digging by auger was carried out by one person to reduce variation.

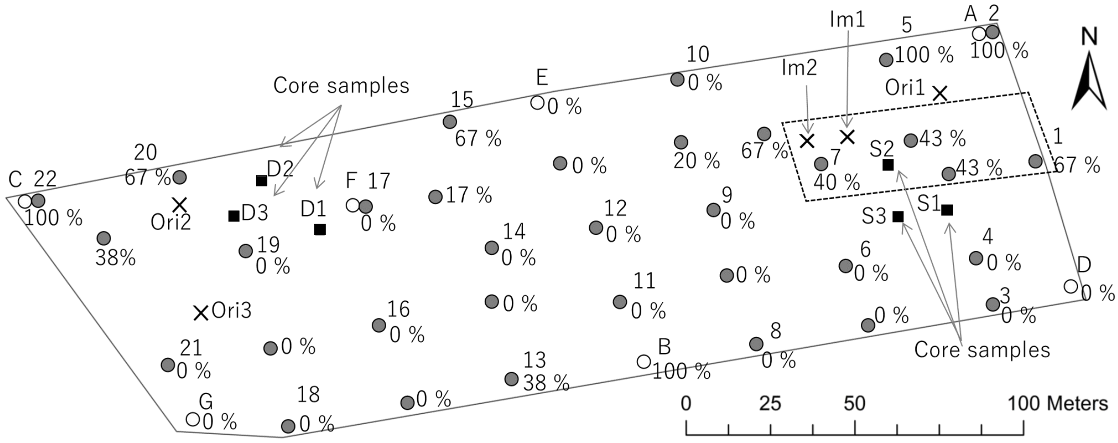



Figure 11. A map of data collection points.
Sampling points were selected to cover the entire study plot for mapping purposes. Measurement of elevation and depth of hard layer and soil sampling were carried out at all the circle points. White circle points (A to G) are the representative points with the highest or lowest mortality rate of the trees. Gray circle points with numbers (1–22) represent the sampling points for a series of chemical and statistical analysis shown in Table 5, 7 and 8, and Figure 17 and 18. Cross points represent the sampling points for surface soil at the base of the trees: Imported soil (Im1 and Im2) and Original soil (Ori1, Ori2 and Ori3). The dotted line represents the area where the soil importing treatment was conducted when seedlings were planted in 2008. Black square points represent the sampling points for core samples in two separated area groups. 'Deep' and 'Shallow' refer to the depth of the hard clay layer.

## 4.2.5. Soil sampling

The sampling points are shown in Figure 11. Sampling points were selected to cover the entire plot area for mapping. To understand the general situation of sand sedimentation and salt precipitation of the deeper soil profile in the areas with low or high mortality rate of trees, seven representative points were selected (A, B, C, D, E, F, and G) for soil texture and ECe determination using auger with 7 cm diameter from three profiles, 0–20 cm, 50–60 cm, and 80–100 cm. Soil samples at the other 22 points (1–22) were collected at depths of 0–20 cm, 50 cm, and 80–100 cm for soil texture and chemical analysis. These sampling points were included for the collection of topographic data mentioned above. Because making a saturation paste consumes more soil than needed for other types of analysis, the weight of soil samples collected from 0–20 cm, 50–60 cm, and 80–100 cm at the representative points, and samples from 0–20 cm and 80–100 cm at the other 22 sampling points was 250 g. Samples taken from 50 cm at the other 22 sampling points (not representative points) weighed 15 g. Each sampling point was made between trees on a ridge.

Soil cores were also sampled to measure the bulk density and hydraulic conductivity of the hard clay layer. The purpose was to show the different properties of the hard clay layer and the overlying sand sediment. For this reason, core samples were collected at

30 cm and 50 cm depths in two areas with deep sand sediment (more than 100 cm depth; D1, D2, and D3) and shallow sand sediment (30–40 cm; S1, S2, and S3). To confirm soil improvement from the sand importation treatment conducted in 2008, surface soil (0–20 cm) was collected from the base of the trees by hand from the treated area of the plot. These samples were named Im1 and Im2. For comparison, the original soil collected from the base of the trees at non-treated

areas in the plot was named as Ori1, Ori2, and Ori3.

### 4.2.6. Physical properties of soil

All the soil samples except for core samples were air-dried and sieved through a 2-mm mesh before soil texture analysis. Soil texture was determined by a pipette-sieving method (Jackson *et al.*, 1986). Sand ratio was determined by mass percent of sand (0.02–2 mm in diameter).

To describe the properties of the hard clay layer in the plot, bulk density and hydraulic conductivity of soil core samples were measured. The falling head method was applied to measure hydraulic conductivity. Values were determined by taking the average of the three replicates.

### 4.2.7. Chemical properties of soil

All the soil samples except for core samples were air-dried and sieved through a 2 mm mesh before analysis. A saturation paste was made to provide water extractions for the measurement of pH, electrical conductivity (ECe) and soluble cations ($Na^+$, $K^+$, $Ca^{2+}$ and $Mg^{2+}$). Air-dried soil was mixed with deionized water to make the saturation paste. pH was measured by a composite electrode meter (F-74BW, electrode 9615S-10D, Horiba, Kyoto, Japan). ECe was measured by a conductivity meter (F-74BW, electrode 3551-10D, Horiba, Kyoto, Japan). Cations were determined by atomic absorption spectrophotometry (AA-7000, Shimadzu, Kyoto, Japan). Methods for the assessment of salinity and sodicity are well developed. The sodium adsorption ratio (SAR) was used for the index of sodicity hazard for soil and ECe was used for the index of salinity hazard. The classification of soil water extracts was based on the US Salinity Laboratory (USSL) criteria (Richards, 1969). SAR was determined by the following equation,

$$\mathrm{SAR} = \frac{[\mathrm{Na}^+]}{\sqrt{1/2([\mathrm{Ca}^{2+}] + [\mathrm{Mg}^{2+}])}}$$

(All ions in $\mathrm{mmol_c\ L^{-1}}$)

## 4.2.8. Statistical analysis

To show the distribution of variables (plant height, relative elevation, depth of hard clay layer, ECe and SAR), ArcGIS 10.2.1 (ESRI, California, USA) was used for the spatial analysis. The correlation among variables was determined by Pearson correlation. Multiple linear regression analysis was conducted by a stepwise method for optimal predictions of plant height and mortality rate. Sigma Plot 11.0 (Systat Software Inc., CA, USA) was used for the statistical analysis. To link the plant height data to every soil sampling point, the average height of living trees within a 5 m radius from a sampling point was calculated. The mortality of the trees at every soil sampling point was also calculated within the same 5 m radius. Dead trees could be distinguished by a short shoot less than 40 cm and without any leaves.

## 4.3. Results

## 4.3.1. Temperature dynamics in soil

The soil temperature at the surface 10 cm deep had a big amplitude between summer and winter ranging 40.8 to -17.3 Celsius degree. The amplitudes of the depths at 30 cm and 50 cm was smaller than that at 10 cm ranging 32.5 to -11.1 and 31.4 to -10.3 respectively. Daily amplitude was also big in 10 cm deep, but stable the other deeper profiles.

The soil temperature fell below zero degree Celsius from the middle November 2014 until the middle March 2015, during which snow falling occurred accumulated about 20-30 cm on the ground according to the observation by the villagers. In the middle of March in 2015, when the surface temperature went above zero degree, the snow started to melt supplying a big amount of water to the ground. However, there were frequent frosts of the water until the end of March. This repeated freeze-thaw cycle was seen in the north-east and the central-south areas, where the melted snow flew and pooled. While in the other areas, water was not pooled on the ground after the snow thawing. The soil temperature dramatically increased from June and kept the high degree until the middle August (the end of monitoring) (Figure 12).

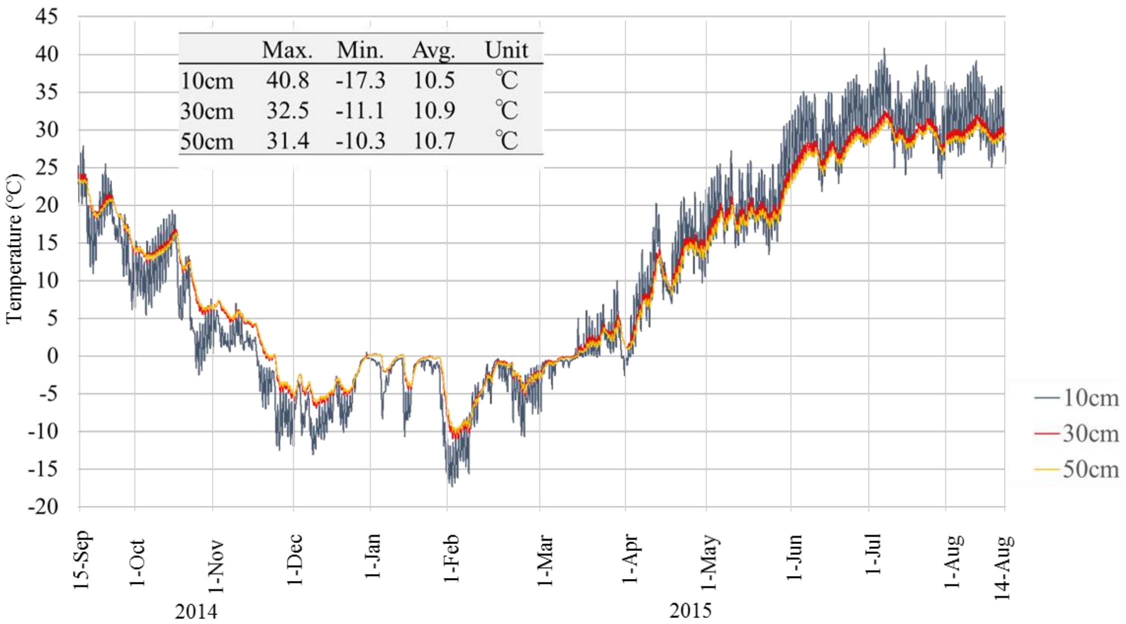



Figure 12. Dynamics of soil temperature
The soil temperature at three depths, 10cm, 30cm and 50cm was measured for eleven months.

## 4.3.2. Distribution of plant height in the plot

The height of black saxaul trees varied from 15 cm to 160 cm in spite of their similar age (Figure 13). Within three areas of the plot; east-north, south-center, and west-north, most planted seedlings seemed to fail to take root, and even living trees were stunted with little leaf and branch growth. Since many of the trees died during the seedling stage, stalk height was limited to less than 40 cm. In other areas, all trees had branches and photosynthetic shoots. However, their height varied from 40 cm to 160 cm. This situation indicated that the conditions in the plot were not homogeneous as were other sites participating in reforestation projects in this region.

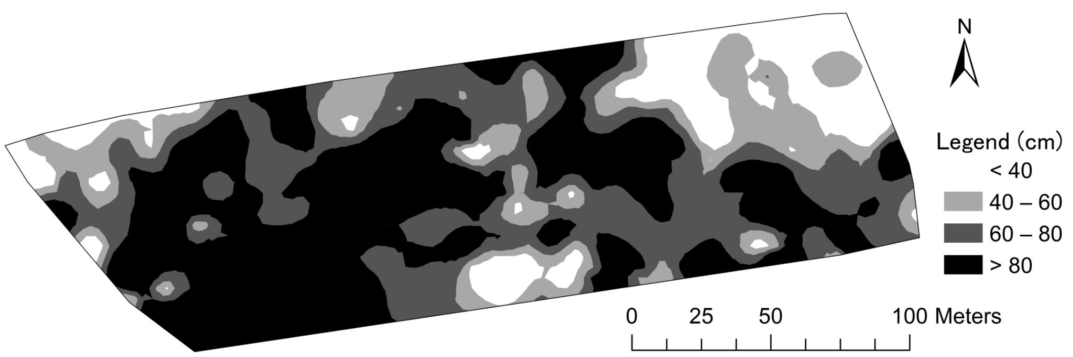



Figure 13. A map of height of black saxaul
Total number of the trees within the study plot is about 1,800 and includes dead trees. The height of 356 trees picked every five trees were used in this figure.

## 4.3.3. Soil texture pattern favorable for seedling survival

During field observations, we found sandy soil accumulated in vegetative areas. In the Soil Map of the World (FAO-UNESCO,1971-1981), the soil type of the plot is classified as Calcic Yermosols, a typical desert soil with substantial accumulation of carbonates under extremely arid environment. The World Reference Base (IUSS Working Group WRB. 2014) includes this soil type in the Gypsisols. Solonetz and Yermosols should be the potential soil types in this region, but no natric horizon was found in the plot. In Solonetz soil, natric horizon is formed by clay illuviation from the upper layer, where clay content gradually changes. Within the study site, the soil texture suddenly changed, the hard clay layer is sedimentary rather than pedogenic horizon. The soil texture pattern at profile depths of 0–20 cm, 50–60 cm and 80–100 cm was evaluated for seven representative points which were divided into two groups based on the seedling mortality rate: high (100%: A, B and C) and low (0%: D, E, F and G) mortality (Figure 14). Sandy textured soils were observed within all profiles of the low-mortality group (D, E, F and G), while the high mortality group showed different patterns, and contained silt and clay rich soils either entirely (A) or partially (B and C). ECe values were high in soils with a high content of silt and clay and low in sandy profiles. Even if a section of the profile was sandy, the existence of silt and clay rich soils could be critical for the survival of the trees. These results suggested that suitable depths of sandy sediments formed an adequate environment for seedlings to take root, while silt and clay rich soil adversely affected seedling establishment.

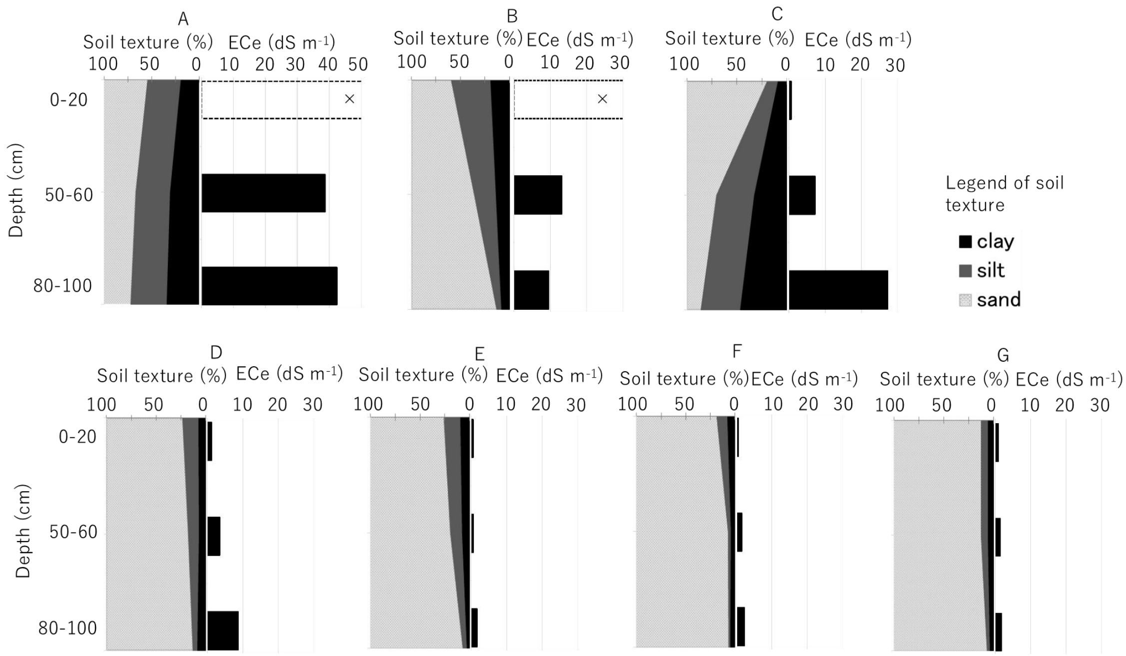



Figure 14. Soil texture and ECe in representative sampling points

Mortality rate of trees at three sampling points (A, B and C) was 100 %. Other four sampling points (D, E, F and G) was in 0% mortality rate. '×' in A and B means that ECe of the samples was not shown by EC meter because the values were over the upper limit of measurement.

This finding is supported by the failure of the sand importing method applied to some seedlings planted at the north-east corner of the plot. As shown in Figure 15, the imported soil (Im1 and Im2) showed a high content of sand, 67% and 77%, respectively. The ECe of Im1 and Im2 were 1.2 and 0.8 dS $m^{-1}$, respectively. The texture of Ori1 (original soil) was silt and clay rich with a high ECe (7.9 dS $m^{-1}$), which was the original property of the surface soil at this area. The proportion of sand and the ECe of Im1 and Im2 were at the same level as those in Ori2 and Ori3, which were original soil and taken from the area with a low mortality rate of seedlings (Figure 15). However, the seedlings planted near Im1, Im2 and Ori1 showed stunted growth probably because the roots were exposed to the silt and clay rich soil as shown in representative point A (see Figure 13 and Figure 14).

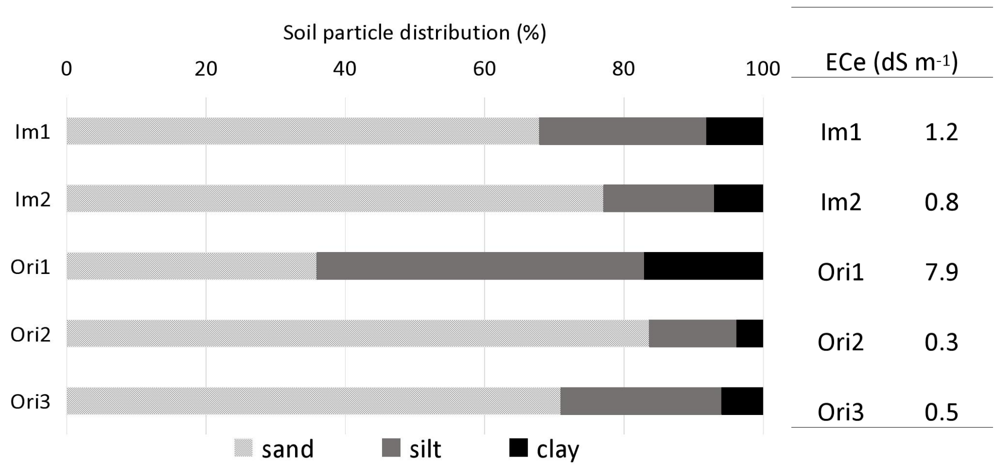



Figure 15. Soil texture and ECe of surface soil (0–20 cm) applied into the base of trees and original soil

"Im" represents the imported sandy soil samples and "Ori" represents original soil. Sampling points are shown in Figure 12.

#### 4.3.4. Distribution of topographic factors

The difference in relative elevation was a maximum of 104 cm (Figure 16a). A moderate slope gradient spread from the highest point. The depth of the hard clay layer ranged from 35 cm to 175 cm. The shallowest depth of this layer was located in the east and the north-west corner. In the area from the west to the north-central, light textured soil had accumulated to depths of more than 100 cm (Figure 16b).

By combining these two topographic factors, the depth variation of the hard clay layer below the surface was estimated (Figure 16c). The hard layer had a maximum difference in depth of 145 cm.

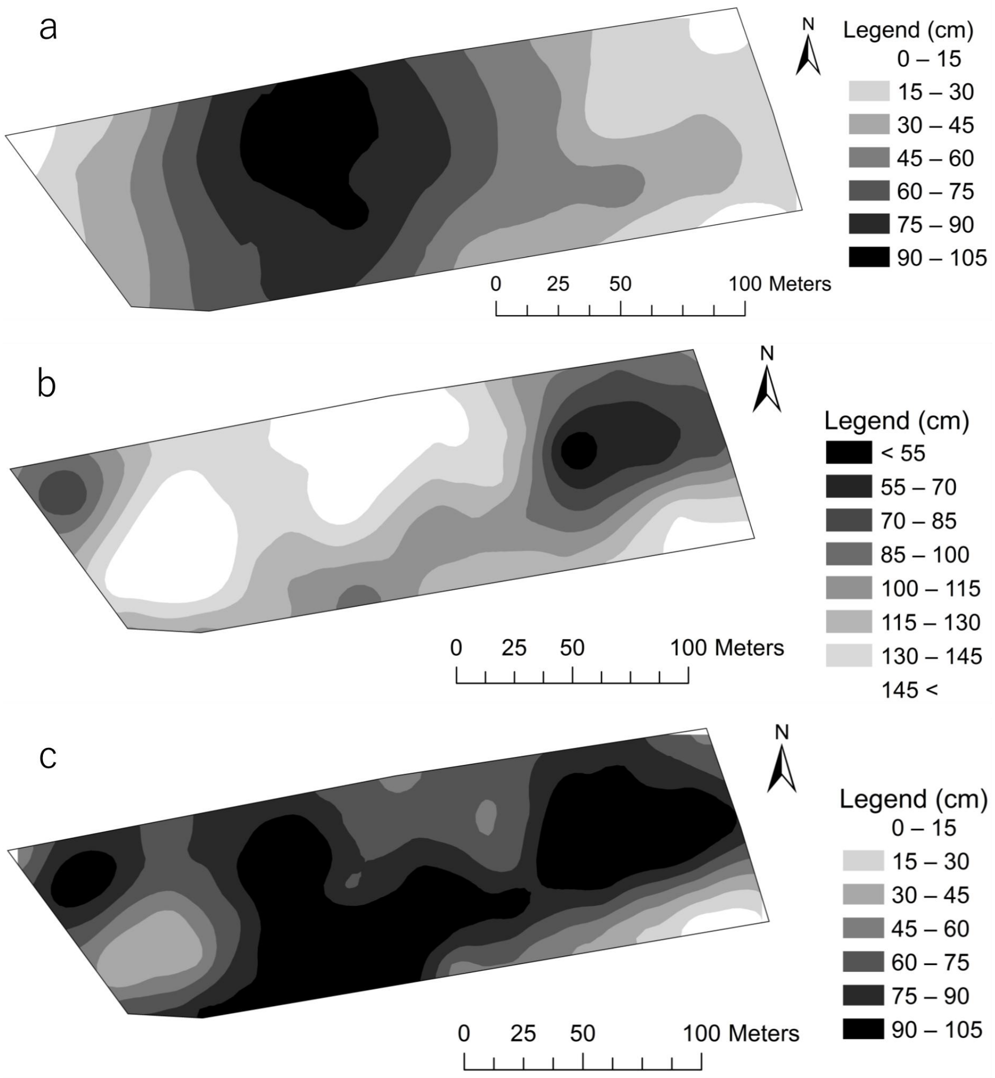



Figure 16
a. Relative elevation of surface to the lowest point (north-west corner). Dark colors represent higher elevation.
b. The depth from surface to hard clay layer at each point. Light colors show that the hard layer exists at deeper profiles.
c. Relative elevation of hard clay layer. This was determined by taking difference between relative elevation and the depth from surface to hard clay layer. Dark colors represent higher elevation.

## 4.3.5. Chemical and physical properties of soil

Table 5 shows the chemical properties of the soil in the plot. There was a large range in ECe among the samples (between 0.6 and 36 dS $m^{-1}$). $Na^{+}$ dominated the soluble cations present, followed by $Ca^{2+}$. The behavior of ECe and SAR values almost corresponded and all the samples with high SAR (more than 13) were categorized as having moderate or high ECe (more than 8 dS $m^{-1}$). This suggested that sodium concentration predominantly determined the salinity level in the plot. The pH ranged from 7.4 to 10 indicating that the soil was moderately to strongly alkaline. The pH of samples with high ECe tended to be lower.

The bulk density and the hydraulic conductivity of the soil collected at two different points, where the hard layer appeared at shallow or deep depths, are shown in Table 6. The soils from the 'deep' group were all sandy sediments at both 30 cm and 50 cm depths, but the soils from the 'shallow' group contained a hard layer at 30 cm and at 50 cm depth only the hard layer was present. The bulk density of the hard layer was lower (1.21–1.46 Mg $m^{-3}$) than that of sand sediment (1.44–1.56 Mg $m^{-3}$), meaning that the soil of the hard layer contained more dispersible particles such as silt and clay. Also, the hydraulic conductivity had a clear difference between the two groups, although one sample in the 'shallow' group showed the similar characteristics to 'deep' group samples ($1.5\times10^{-5}$ m $sec^{-1}$). The soils of the hard layer had lower conductivity ($7.5\times10^{-7}$–$8.0\times10^{-6}$ m $sec^{-1}$) than sandy sediments ($1.0\times10^{-5}$–$4.3\times10^{-5}$ m $sec^{-1}$). This suggested that the hard layer let very little water through.

Table 5 Chemical composition of samples

| Sampling point | Depth (cm) | $Ca^{2+}$ | $Mg^{2+}$ (mmolc $L^{-1}$) | $Na^{+}$ | $K^{+}$ | SAR (mmolc $L^{-1}$)$^{0.5}$ | ECe dS $m^{-1}$ | pH |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-20 | 5.8 | 2.1 | 9.6 | 1.7 | 5 | 1.8 | 9.3 |
| | 80-100 | 23.4 | 15.0 | 196 | 1.2 | 45 | 26 | 8.0 |
| 2 | 0-20 | 23.5 | 11.1 | 201 | 3.0 | 48 | × | 8.8 |
| | 80-100 | 17.5 | 14.3 | 175 | 1.0 | 44 | 16 | 8.4 |
| 3 | 0-20 | 2.8 | 0.7 | 4.5 | 2.0 | 3 | 0.6 | 9.4 |
| | 80-100 | 33.1 | 13.6 | 22.2 | 2.7 | 5 | 6.2 | 8.9 |
| 4 | 0-20 | 6.7 | 1.4 | 7.0 | 1.7 | 3 | 1.1 | 9.4 |
| | 80-100 | 34.9 | 11.1 | 15.6 | 2.4 | 3 | 3.7 | 8.7 |
| 5 | 0-20 | 23.1 | 9.4 | 181 | 3.0 | 45 | 17 | 8.9 |
| | 80-100 | 17.5 | 14.3 | 175 | 1.0 | 44 | 20 | 8.1 |
| 6 | 0-20 | 5.6 | 1.5 | 3.2 | 2.2 | 2 | 0.9 | 9.4 |
| | 80-100 | 40.8 | 8.9 | 40.8 | 1.8 | 8 | 8.9 | 8.4 |
| 7 | 0-20 | 16.0 | 6.9 | 40.4 | 3.2 | 12 | 6.5 | 9.3 |
| | 80-100 | 16.8 | 11.2 | 162 | 2.7 | 43 | 25 | 7.4 |
| 8 | 0-20 | 6.3 | 4.8 | 14.1 | 1.9 | 6 | 2.6 | 9.5 |
| | 80-100 | 46.2 | 15.2 | 45.2 | 2.1 | 8 | 9.4 | 8 |
| 9 | 0-20 | 4.0 | 1.3 | 10.4 | 1.9 | 6 | 1.3 | 9.6 |
| | 80-100 | 46.2 | 13.7 | 42.9 | 2.7 | 8 | 9.2 | 8.9 |
| 10 | 0-20 | 6.9 | 5.2 | 11.6 | 1.0 | 5 | 1.9 | 9.1 |
| | 80-100 | 15.9 | 9.9 | 141 | 4.2 | 39 | 25 | 9.2 |
| 11 | 0-20 | 98.0 | 17.3 | 209 | 0.4 | 28 | × | 8.7 |
| | 80-100 | 20.3 | 6.1 | 119 | 2.0 | 33 | 20 | 8.1 |
| 12 | 0-20 | 4.1 | 1.3 | 5.6 | 1.9 | 3 | 0.9 | 9.5 |
| | 80-100 | 42.9 | 16.9 | 39.4 | 1.4 | 7 | 7.2 | 8.4 |
| 13 | 0-20 | 2.1 | 0.6 | 11.2 | 0.9 | 10 | 1.5 | 10.0 |
| | 80-100 | 19.5 | 8.8 | 163 | 0.6 | 43 | 15 | 7.9 |
| 14 | 0-20 | 3.6 | 1.5 | 4.2 | 1.2 | 3 | 0.8 | 9.4 |
| | 80-100 | 40.1 | 14.4 | 41.1 | 1.7 | 8 | 7.3 | 8.7 |
| 15 | 0-20 | 28.8 | 6.2 | 15.7 | 1.8 | 4 | 2.7 | 8.6 |
| | 80-100 | 20.5 | 7.7 | 17.9 | 1.1 | 5 | 3.9 | 9.0 |
| 16 | 0-20 | 6.5 | 3.4 | 8.5 | 1.7 | 4 | 1.7 | 9.3 |
| | 80-100 | 16.3 | 11.3 | 155 | 0.6 | 42 | 24 | 8.4 |
| 17 | 0-20 | 4.3 | 1.2 | 3 | 0.7 | 2 | 0.6 | 9.0 |
| | 80-100 | 18.1 | 6.5 | 18 | 0.8 | 5 | 3.3 | 8.9 |
| 18 | 0-20 | 5.8 | 1.8 | 5.0 | 1.3 | 3 | 0.8 | 9.5 |
| | 80-100 | 14.6 | 3.9 | 14.0 | 1.2 | 5 | 3.2 | 8.9 |
| 19 | 0-20 | 10.5 | 5.7 | 5.7 | 3.4 | 2 | 3.0 | 9.1 |
| | 80-100 | 43.9 | 9.9 | 40.3 | 1.9 | 8 | 9.4 | 8.3 |
| 20 | 0-20 | 21.7 | 6.2 | 15.0 | 3.5 | 4 | 6.4 | 9.3 |
| | 80-100 | 50.1 | 17.2 | 198 | 2.6 | 34 | 30 | 8.3 |
| 21 | 0-20 | 35.4 | 6.9 | 10.7 | 2.3 | 2 | 3.3 | 8.4 |
| | 80-100 | 14.8 | 4.3 | 16.5 | 0.9 | 5 | 3.1 | 8.1 |
| 22 | 0-20 | 12.0 | 9.1 | 8.6 | 2.8 | 3 | 2.8 | 9.3 |
| | 80-100 | 11.6 | 8.7 | 126 | 0.7 | 39 | 19 | 9.4 |

'×' represents that ECe of the sample was over measurement limitation.

Table 6 Bulk density and hydraulic conductivity of sand sediment and hard layer

| Depth of hard layer | Sampling point | Depth (cm) | Bulk density ($Mg\ m^{-3}$) | Hydraulic conductivity ($m\ sec^{-1}$) |
|---|---|---|---|---|
| Deep (more than 100 cm) | D1 | 30 | 1.44 | $1.8\times10^{-5}$ |
| | D2 | 30 | 1.56 | $1.1\times10^{-5}$ |
| | D3 | 30 | 1.52 | $1.0\times10^{-5}$ |
| | D1 | 50 | 1.48 | $3.1\times10^{-5}$ |
| | D2 | 50 | 1.5 | $2.7\times10^{-5}$ |
| | D3 | 50 | 1.5 | $4.3\times10^{-5}$ |
| Shallow (30 – 40 cm) | S1 | 30 | 1.31 | $8.0\times10^{-6}$ |
| | S2 | 30 | 1.46 | $1.5\times10^{-5}$ |
| | S3 | 30 | 1.29 | $4.8\times10^{-6}$ |
| | S1 | 50 | 1.21 | $7.5\times10^{-7}$ |
| | S2 | 50 | 1.28 | $6.1\times10^{-6}$ |
| | S3 | 50 | 1.34 | $6.0\times10^{-6}$ |

Core samples of the 'Deep' group were soil from sand sediment. Core samples of the 'Shallow' group represent the soil from hard layer.

### 4.3.6. Distribution of salinity and sodicity

Figure 17 shows the distribution of ECe and SAR at the surface (0–20 cm) and subsoil (80–100 cm). At the surface, saline soil layer (4–16 dS $m^{-1}$) was found in the north-east corner of the plot, while the other areas were not affected by salinity (< 4 dS $m^{-1}$). However, at 80–100 cm depths, a large area was affected by salinity at slight (4–8 dS $m^{-1}$) or moderate levels (8–16 dS $m^{-1}$). The north-east corner was more severely affected by salts at 80–100 cm depth (more than 16 dS $m^{-1}$). The north-central, south-east and the south-west corners remained unaffected.

A high level of sodicity was found at the surface in the south-central area (13 < SAR < 26) and the north-east corner (SAR > 26), while in other places sodicity was lower in the soil profile. These two affected areas at the subsoil expanded in size and the north-west corner was also severely affected (SAR > 26). Although the sodium hazard affected most areas at 80–100 cm, the north-central, the south-east and the south-west sections remained unaffected. This pattern was also seen in ECe at this depth.

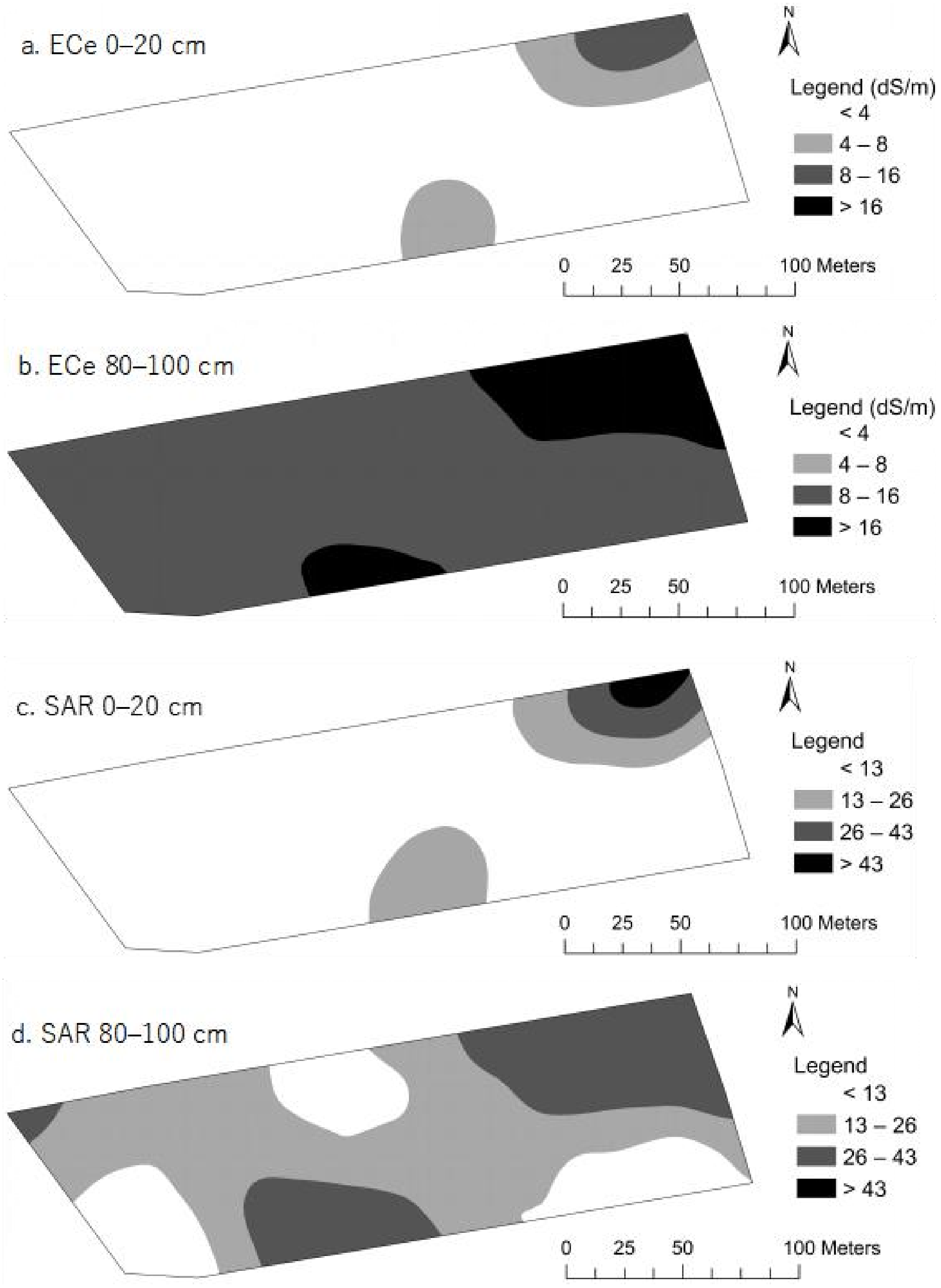



Figure 17. A map of ECe and SAR at 0–20 cm and 80–100 cm
Categories of legend in ECe (a and b) and SAR (c and d) are based on the U.S. Salinity Laboratory classification. ECe: < 4: normal, 4–8: slightly saline, 8–16: moderately saline, 16 <: severely saline. SAR: < 13: None to slight 13–26: moderate, 26–43: high, > 43: very high

### 4.3.7. Relationship between plant height and environmental factors

According to Pearson correlation analysis, the height of living plants had a significantly positive correlation with the depth of the hard layer ($p < 0.01$) and sand ratio, and negative correlation with ECe and SAR (all at 80–100 cm depth, $p < 0.01$). However, sand ratio, ECe and SAR at 0–20 cm and relative elevation did not show significant correlations with plant height. Then, the relationship between these factors and plant height is shown in a scatter plot (Figure 18). However, most of the relationship between important soil parameters and plant height are not linear (see the Fig 18(b, d, f)). The use of nonlinear regression models would be more justified for the parameters. Also, linear regression models are distorted by some outliers for EC at 0-20 cm and SAR at 0-20 cm (see the Figure 18(e, g)). Without these outliers, the *r* values would be much different. When the mortality rate of sampling points was shown in scatter plots, the group with a low mortality rate (0–20%) and the group with higher mortality rates could be differentiated by the depth of the hard clay layer, the sand ratio at 80–100 cm, SAR at 80–100 cm and ECe at 80–100 cm, but not by relative elevation, sand ratio at 0–20 cm, SAR at 0–20 cm and ECe at 0–20 cm. These results suggest that the properties near the soil surface do not indicate site quality, but rather reveal the importance of subsoil properties.

A correlation matrix between independent variables is shown in Table 7, in which multicollinearity was present among the variables. After eliminating unnecessary variables, multiple regression analysis showed that plant height could be predicted from a combination of the independent variables: depth of hard layer and sand ratio at 0–20 cm, but only the depth of the hard layer appeared to account for the ability to predict plant height ($p < 0.01$). Also, mortality rate could be predicted from a combination of the independent variables: depth of hard layer and ECe at 80–100 cm, but only depth of hard layer appeared to account for the ability to predict mortality rate ($p < 0.01$) (Table 8). These results suggest that both mortality rate and plant height can be significantly determined by the depth of the hard layer (i.e. depth of sand sediment).

Because potassium is an essential nutrient for plant metabolism and other bioactivity, the potassium concentration was expected to have a significant relationship with the plant height. However, we found no significant correlation between the potassium content and plant height in this study.

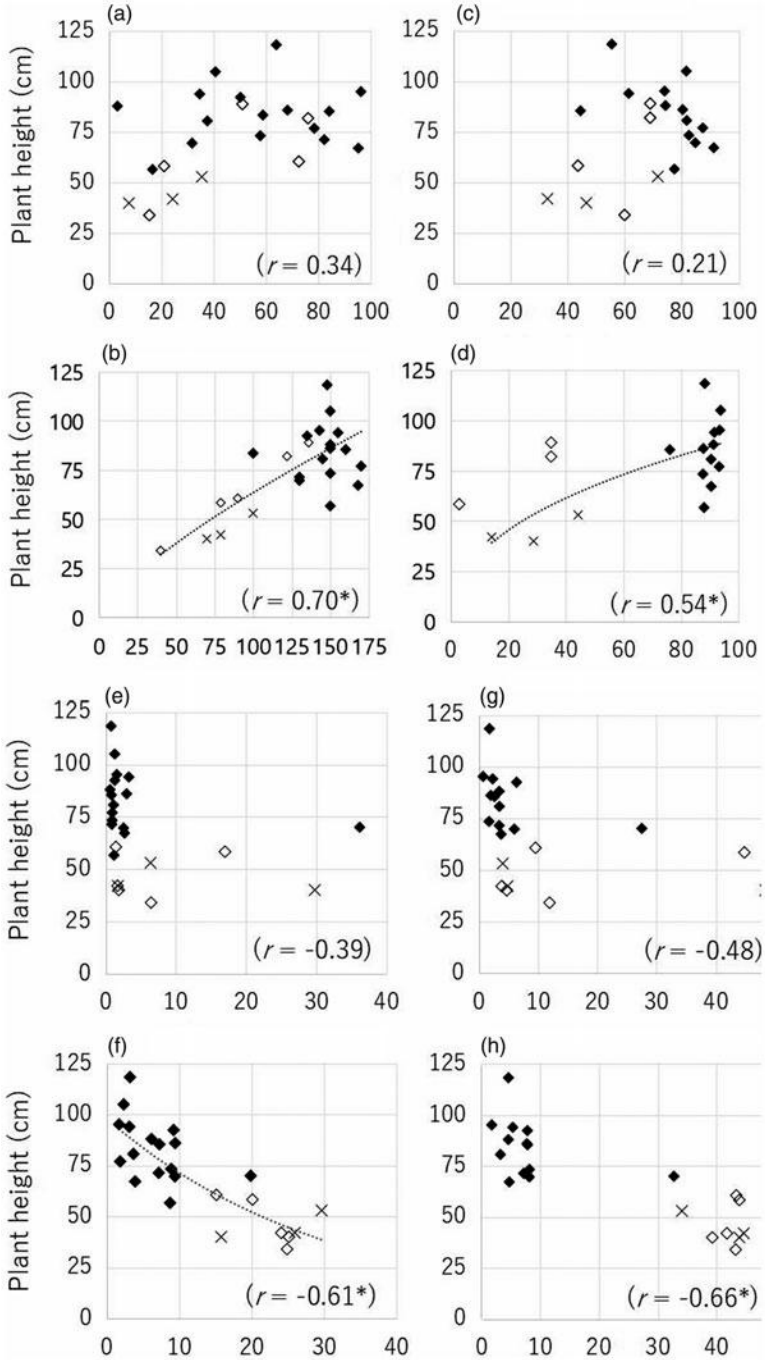



Figure 18. Relationships between plant height and soil environmental factors

The average height of living trees standing inside a circle of 5 m radius from a sampling point was calculated. Different symbols represent the levels of mortality (◆: 0 %, ◇: less than 50 %, ×more than 50 %). Three points with 100 % mortality were excluded because the plant height could not be measured without any alive tree. '*r*' is a correlation coefficient of each relationship determined by Pearson correlation. * means a significance with $p < 0.01$. The explanatory variables in eight plots are, a: relative elevation, b: depth of hard layer, c: sand ratio at 0 – 20 cm, d: sand ratio at 80 – 100 cm, e: ECe at 0 – 20 cm, f: ECe at 80 – 100 cm, g: SAR at 0 – 20 cm and h: SAR at 80 – 100 cm.

Table 7. Correlation matrix among independent variables

| | | | (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Relative elevation | (cm) | (a) | 1 | -.51** | .50** | .24 | .46* | -.23 | -.35 | -.34 | -.35 |
| Mortality rate | (%) | (b) | | 1 | -.80** | -.56** | -.59** | .35 | .50* | .49* | .71** |
| Depth of hard layer | (cm) | (c) | | | 1 | .60** | .67** | -.48* | -.78** | -.54* | -.85** |
| Sand raitio at 0–20 cm | (%) | (d) | | | | 1 | .49* | -.20 | -.46* | -.26 | -.51* |
| Sand raitio at 80–100 cm | (%) | (e) | | | | | 1 | -.25 | -.86** | -.59** | -.97** |
| ECe at 0–20 cm | (dS $m^{-1}$) | (f) | | | | | | 1 | .34 | .85** | .43 |
| ECe at 80–100 cm | (dS $m^{-1}$) | (g) | | | | | | | 1 | .28 | .89** |
| SAR at 0–20 cm | ($mmol_c$ $L^{-1}$)$^{0.5}$ | (h) | | | | | | | | 1 | .52* |
| SAR at 80–100 cm | ($mmol_c$ $L^{-1}$)$^{0.5}$ | (i) | | | | | | | | | 1 |

Note: One (*) asterisk and two (**) asterisks show $p$ values less than 0.05 and 0.01, respectively

Table 8. Results of multiple linear regression analysis for plant height and mortality rate

Plant height = 2.97 + (0.78 × Depth of hard layer (cm)) - (0.50 × Sand ratio_0–20 cm (%))

| | Constant | Depth of hard layer (cm) | Sand ratio_0–20 cm (%) | $R^2$ |
|---|---|---|---|---|
| Coefficient | 2.97 | 0.78 | -0.50 | 0.64 |
| Standard error | 19.2 | 0.15 | 0.34 | |
| t | 0.16 | 5.33 | -1.45 | |
| *p* | 0.88 | < 0.001** | 0.16 | |

Note: Two (**) asterisks in tables show $p$ value less than 0.01

## 4.4. Discussion

It is known that saxaul species prefer sandy soil (Herbel *et al.*, 1981; Winter 1981; Khassanov *et al.*, 1994). We confirmed that at least 100 cm depth of sand had accumulated in the areas where all black saxaul trees were in good condition without any stunted growth. However, when even partly silt and clay rich soil was found within 100 cm deep from the surface, the mortality rate rose and there was little subsequent growth (Figure 13 and Figure 14). Wei *et al.,* 2007 showed that saxaul seedlings rapidly extended their vertical root just after planting in March until June. During this period, other parts of the plant had little development. However, when the vertical root reached to about 100 cm, the elongation rate decreased and the shoot and the root biomass started to grow at a rapid rate (Wei *et al.*, 2007). Our results also suggested that soil conditions that guarantee high survival rates would be formed by at least 100 cm depth of sand accumulation. This finding can be used as a practical index for site selection. In current reforestation areas, adding sand to the surface soil at depths of 0–30 cm did not increase the survival of the seedlings. This was also supported in the study plot, showing that even seedlings planted in sandy soil could not survive in a severely degraded area although the soil environment at 0–30 cm depths was comparable to that in the area with a high survival rate (Figure 15). Also, the soil texture pattern explained in Figure 14 implied that there was a minimum depth of sand sediment required for the establishment of seedlings from the surface to a depth of 100 cm. Although several studies reported that the elevation affected the soil salinity that caused the decrease of crop yields (Funakawa & Kosaki, 2007; Li *et al.*, 2007; Fan *et al.*, 2012; Nguyen *et al.*, 2014), the significant influence of relative elevation on plant height was underrepresented in the study plot. Rather, the depth of the hard layer, that is the thickness of sand sediments, strongly determined the survival of seedlings and plant height (Figure 18). Although potassium ions play an important role in plant growth (Aleman *et al*., 2011), a positive effect of soil potassium content was not detected in this study. The possible reason is that other negative factors, such as high salinity and the physical impedance of the soil, were too strong to see the positive effect of potassium ions on growth.

The main issue in the study plot that restricted root extension may be due to osmotic stress caused by a high concentration of salt and physical impedance caused by sodium hazard. Because evaporation exceeds precipitation in arid areas, the salt trapped in clayey soils are precipitated by active evapotranspiration rather than leaching by water. (Singh *et al.*, 2013; Ahmad *et al.*, 2015). On the other hand, sand has high hydraulic conductivity that forms a favorable condition for plants with little osmotic stress through the leaching process (Levy *et al.*, 2003; Ahmad *et al.*, 2015). Correspondence in the behavior of ECe and SAR suggested that the contribution of sodium ions among the soluble salts was the main factor in the plot. The sodium hazard was especially severe in subsoil with a depth of 80–100 cm (Figure 17). High levels of SAR create problems in soil permeability by disrupting aggregates which lead to poor infiltration, aggregate stability, or aeration (Rengasamy & Olsson, 1991; Ivits *et al.*, 2013). Low water permeability was observed in the field at the north-east corner and the south-central area of the study plot where a lot of melted snow was pooled. If the roots are soaked during the snow thawing period, this raises levels of seedling mortality.

Finally, the plot setting should be carefully considered because the micro topography that black saxaul trees responded to in the study site changed over a much smaller scale than the size of a plot in one of the reforestation projects (several hectares). Large-scale reforestation aiming at homogeneous stands would in turn decrease the efficiency of planting.

The environment of the study plot was not suitable for the survival of *H. aphyllum*, considering the inhomogeneous growth including stunted or dead plants. Because of that, the study plot met the research purpose to reveal the environmental limitations for *H. aphyllum* to survive in the region. However, the plot environment did not cover the entirety of the Aral region including the dry seabed sites. Therefore, it is necessary to test whether or not the methodology is applicable at the dry seabed sites.

## 4.5. Conclusion

This study showed that zero mortality of seedlings and good subsequent growth could be achieved when sandy sediments accumulated at more than 100 cm deep. These formed a favorable environment with little danger of salinity and sodicity hazards. Our results suggest that conditions at both shallow soil depths and in deeper subsoils need to be assessed in the selection of planting sites for black saxaul seedlings. Although imported sand is applied to the base of trees in current reforestation projects to improve the soil condition, this treatment seems to provide little improvement for outcomes. Also, a suitable planting size needs to be assessed, considering the heterogeneous condition of the soil at small scales and the significant responses of seedlings to those soil conditions. Finally, it is suggested to test the effectiveness of these findings at other sites in the Aral region including the dry seabed sites in the future.

## 4.6. References


Ahmad S, Ghafoor A, Akhtar ME, Khan MZ. (2016) Implication of Gypsum Rates to Optimize Hydraulic Conductivity for Variable-Texture Saline–Sodic Soils Reclamation. *Land Degradation & Development* 27(3): 550-560. DOI: 10.1002/ldr.2413

Aleman F, Nieves-Cordones M, Martinez V, Rubio F. (2011) Root $K^+$ acquisition in plants: the Arabidopsis thaliana model. *Plant and Cell Physiology 52*(9):1603-1612. DOI: 10.1093/pcp/pcr096

Buras A, Wucherer W, Zerbe S, Noviskiy Z, Muchitdinov N, Shimshikov B, Zverev N, Schmidt S, Wilmking M, ThevsN. (2012) Allometric variability of haloxylon species in Central Asia. *Forest Ecology and Management* 274:1–9. DOI: 10.1016/j.foreco.2012.02.023

Dexter AR. (2004) Soil physical quality: Part I. Theory, effects of soil texture, density, and organic matter, and effects on root growth. *Geoderma* 120: 201–214. DOI: 10.1016/j.geoderma.2003.09.004

Fan X, Pedroli B, Liu G, Liu Q, Liu H, Shu L. (2012) Soil salinity development in the yellow river delta in relation to groundwater dynamics. *Land Degradation & Development* 23: 175–189. DOI: 10.1002/ldr.1071.

Food and Agriculture Organization (FAO) UNESCO. 1971–1981. Soil Map of the World, volume VIII North and Central Asia, Rome.

Funakawa S, Kosaki T. (2007) Potential risk of soil salinization in different regions of Central Asia with special reference to salt reserves in deep layers of soils. *Soil Science & Plant Nutrition* 53: 634–649. DOI:10.1111/j.1747-0765.2007. 00186.x

Gintzburger G, Toderich KN, Mardonov BK, Mahmudov M. (2003) Rangelands of the arid and semi-arid zones in Uzbekistan. V. Howe and CIRAD Editing and Publication Service, France426.

Herbel, Carlton H, Robert F Barnes, Harold F Heady, Leonard N Purdy. (1981) Range Research in the Soviet Union. *Rangelands* 3 (2):61-63. http://www.jstor.org/stable/3900168

IUSS Working Group. (2014) World reference base for soil resources 2014 international soil classification system for naming soils and creating legends for soil maps. Rome, Italy: FAO.

Ivits E, Cherlet M, Toth T, Lewinska KE, Toth G. (2013) Characterization of productivity limitation of salt-affected lands in different climatic regions of Europe using remote sensing derived productivity indicators. *Land Degradation & Development* 24: 438–452. DOI: 10.1002/ldr.1140.

Jackson ML, Lim CH, Zelazny LW. (1986) Part 1. Physical and mineralogical methods method of soil analysis. 2nd edition. pp. 383–411. *American Society of Agronomy and Soil Science Society of America*, Madison, WI.

Khassanov OK, Rachimova T, Tadzhiev SF. (1994) Biological characteristics of newly cultivated fodder plants for pastures of the arid zone in Uzbekistan. *Genetic Resources and Crop Evolution* 41(3):125-131. DOI: 10.1007/BF00051629

Levy GJ, Mamedov AI, Goldstein D. (2003) Sodicity and water quality effects on slaking of aggregates from semi-arid soils. *Soil Science* 168: 552–562. ISSN: 0038-075X

Li Y, Shi Z, Li F. (2007) Delineation of site-specific management zones based on temporal and spatial variability of soil electrical conductivity. *Pedosphere* 17(2): 156–164. DOI: 10.1016/S1002-0160(07)60021-6

Meshkov VV, Baizakov SB, Yeger AV, Orozumbekov A. (2009) Forest rehabilitation in Kazakhstan. *IUFRO World Series* 20(4): 83-130. IUFRO Headquarters, Vienna, Austria.

Nguyen L, T Watanabe, S Funakawa. (2014) Spatiotemporal variability in soil salinity 7 and its effects on rice (*Oryza sativa* L.) production in the north central coastal region 8 of Vietnam. *Soil Science & Plant Nutrition* 60: 874-885. DOI: 9 10.1080/00380768.2014.961030

Novitskiy ZB. (2012) Phytomelioration in the southern Aralkum. In Aralkum—a man-made desert. Springer: Berlin Heidelberg: 387–406. DOI: 10.1007/978-3-642-21117-1_16

Rengasamy P, Olsson KA. (1991) Sodicity and soil structure. *Soil Research* 29: 935–952. DOI: 10.1071/SR9910935

Richards, L A. (1969) Diagnosis and improvement of saline and alkali soils. United States Department of Agriculture: Washington.

Singh K, Mishra AK, Singh B, Singh RP, Patra DD. (2015) Tillage effects on crop yield and physicochemical properties of sodic soils. *Land Degradation& Development* 27: 223–230. DOI: 10.1002/ldr.2266.

Wei, J., Zhang, X., Shan, L., Yan, H., Liang, S. (2007) Seedling growth dynamic of *Haloxylon ammodendron* and its adaptation strategy to habitat condition in hinterland of desert. *Science in China Series D-Earth Sciences*, 50 (suppl I), 107-114. DOI: 10.1007/s11430-007-5006-5

Winter K. (1981) C 4 Plants of high biomass in arid regions of Asia-Occurrence of C 4 photosynthesis in chenopodiaceae and polygonaceae from the Middle East and USSR. *Oecologia* 48(1):100-106. DOI: 10.1007/BF00346994.

# Chapter 5

## Discussion

### 5.1. Authority

Despite a high dependency on forests that provide timber, the lack of institutional capacity to protect and regulate forests under a decentralized authority increases their vulnerability in central Asia (Antonia 2009; MacDicken *et al.*, 2015). In the Aral Sea region, the same structural problem creates administrative divisions in forest management functions. Several authorities, the Forest Office at Kamystybas, the regional Nature Reserve Office, and the head of the district (*akimat*), are responsible for their own lands, some of which overlap. The priority that Qyzylorda province can give to forest preservation is relatively low because the *akimat* is responsible for land use. Additionally, the “territorial inspectors,” who are stationed in the district by the Forest Office, have greater influence on practices at logging sites.

Land use planning in logging areas is agreed upon among these three parties. However, no monitoring of the biomass of the logging area has been conducted, and official statistics on logging are not available. A lack of regional capacity to monitor forests and create forest inventories has led to little official information on the actual situation of the forests and unreliability in the existing official data.

### 5.2. Environmental policy

In the 20th century, the Aral region of Qyzylorda province had a history of resource exploitation and environmental destruction, such as desertification and excessive logging of the *Haloxylon* shrub called black saxaul (Micklin, 1991; Spoor, 1998; Breckle *et al.*, 2012). Therefore, afforestation is the most important priority among the forest management policies. The main goals were rehabilitation of degraded land, increasing the number of saxaul trees, and beneficial returns to the local people. It is necessary for sustainable management that the concept of ecosystem includes constructive relations between the local people and nature. However, the conservation and use of resources are often treated as conflicting demands. The idea of “environmental protection” in the Aral region often excludes the consumption of forest resources by people living here.

As evidenced by the transition of the laws on forest management enforced in the Aral region from 1999 to the present, the protection and use of saxaul wood have gradually become incompatible (Chapter 3; 3.1.1). To promote programs such as *Zhasyl El* (Green Country), the Kazakhstan government, which wants to lead the world in greening (Sehring 2012; World Bank 2011; Meshkov *et al.*, 2009), has established the current system, which relies heavily on tamarisk fuel in exchange for protecting saxaul. However, as this study has clarified, black saxaul is much superior to tamarisk in intensity and duration of fire, while tamarisk is better at catching fire, which means that tamarisk is not a same-quality alternative for saxaul (Chapter 3; 3.3.3.3). Gradually, the goal of afforestation has shifted from "land rehabilitation including benefit return to the local people who use wood materials" to "expansion of greening area." Thus, a situation where conservation and utilization of forest resources are not compatible has been accepted for the last 10 years.

Environmental protection projects supported by the World Bank, UNECE, and the International Fund for Saving the Aral Sea (IFAS) are some examples of large-scale investments on afforestation to restore the Aral Sea ecosystem (World Bank 2011; UNECE 2011). Unfortunately, for many years, saxaul afforestation has had a low success rate, while no progress has been made in afforestation methods. In addition, no substantive discussions have been conducted on the guarantee of saxaul fuel as a profit return, probably because the expansion of planting areas has become the ultimate goal.

## 5.3. Emerging resource problem

The sociological survey of this study confirmed the current situation of the use of alternative fuel timber by surveying both the local residents and the authorities. The important fact obtained is that tamarisk is likely to become endangered as a result of excessive demand, as the number of households that use wood has been increasing in the target district. Furthermore, some people responded that they actually took the branches of young trees, which means that a shortage of biomass has developed and progressed.

The new resource problem is actually a thorny issue, because public opinion is strong that environmental protection and greening promotion should be given priority, but the existence of a new environmental load created by the saxaul-tamarisk trade-off relationship for a protected resource is difficult to see. However, from the viewpoint of risk management, a dependence on only tamarisk for making a livelihood under the pressure of increasing population and different perspectives on fuelwood biomass at logging sites between the authorities and the residents make it very necessary to begin discussions not only with the regional and provincial governors but also with the international investors.

## 5.4. Technical issue

Technical improvement in planting black saxaul is also another urgent issue for future risk management to avoid an excessive demand for tamarisk, as well as to implement conservation policies in the region. Saxaul timber as the beneficial return to the local residents will decrease the environmental load on tamarisk. Increasing the absolute amount of resources by technical improvements in planting black saxaul, which has been a challenging issue for a long time in rehabilitation policy in the Aral region, should also be considered. For example, "strip soil preparation," which treats soil down to 30 cm deep, has been applied for a long time in several reforestation activities (Meshkov *et al*., 2009). However, this study clarified that the current failure in reforestation has resulted from an insufficient understanding of the subsoil environment suitable for the seedling roots, and sand sediments at least 100 cm deep might be required (Chapter 4). This is not a recommendation for the replacement of subsoil, but rather, we are pointing out that more investment on soil assessment is needed to select the best planting sites.

The standard of 100-cm depth of sand sediment is the minimum requirement for saxaul seedlings to take root. If a future use of black saxaul timber for fuel is planned, it is necessary to conduct several assessments using more strict selection criteria for planting sites. Regardless of the circumstances under which resource management should be considered, both in terms of conservation and consumption under severe environmental conditions in the region, the lack of an advanced assessment for the selection of appropriate sites for current projects is not a responsible way to accomplish sustainability in this region. Planting projects should save their financial and human resources not only for large-scale planting and infrastructure for afforestation, but also for careful assessment and resource management for local residents after reforestation.

## 5.5. Perspectives

There are 21 districts with about 4,600 households in the Aral region. Whether wood resources can be continuously used is an issue of critical importance for the residents. Little academic knowledge on wood resources management in this region has been accumulated. In this research, we accurately grasped consumption per household and clarified the situation from the local residents' perspective. What needs to be further clarified in the future are the currently available resources for sustainable forest management. For the local forestry authority, accurate measurement and monitoring of the forest are essential for providing information for appropriate future decision-making and planning of afforestation. An understanding of the natural production cycle of wood species is required to maintain a balance between conservation and consumption.

Although the implementation of logging site assessment and the establishment of a feedback system involving local communities are recommended in this study (Chapter 3), the current administrative system makes it difficult to adopt these recommendations. Also, black saxaul has considerable potential for supporting local fuelwood demands, but this species requires careful management because a large demand may suddenly emerge when harvesting restrictions are lifted. However, the response of provincial and regional authorities to any new requirements will be delayed due to a lack of money and organizational capacity. Investment from the international community should be targeted on these difficulties.

## 5.6. References


Antonia Eastwood, Georgy Lazkov and Adrian Newton (2009) The Red List of Trees of Central Asia, *Fauna & Flora International*, Cambridge, UK.

Breckle, S.W., Wucherer, W., and Dimeyeva, L.A. (2012) Vegetation of the Aralkum, In Aralkum - A Man-Made Desert, Springer Berlin Heidelberg. 127-159. DOI: 10.1007/978-3-642-21117-1_9

MacDicken, K.G., Sola, P., Hall, J.E., Sabogal, C., Tadoum, M., and de Wasseige, C. (2015) Global progress toward sustainable forest management. *Forest Ecology and Management*, 352, 47-56. DOI: 10.1016/j.foreco.2015.02.005

Meshkov, V.V., Baizakov S.B., Yeger A.V., and Orozumbekov A. (2009) Forest rehabilitation in Kazakhstan. *Keep Asia Green*, 4, 83-130.

Micklin, P. (1991) The Water Management Crisis in Soviet Central Asia. No. 905, *The Carl Beck Papers in Russian and East European Studies*. The Center for Russian and East European Studies, Pittsburgh, August.

Sehring, J. (2012) Forests in the context of climate change in Kazakhstan (No. 60). Discussion Paper, *Zentrum für internationale Entwicklungs-und Umweltforschung.*

Spoor, M. (1998) The Aral Sea basin crisis: Transition and environment in former soviet Central Asia. *Development and Change*, *29*(3), 409-435.

UNECE (2011) Launch of a regional project on the forestation of the dry bed of the Aral Sea (published on 13 October 2011) http://www.unece.org/index.php?id=26725

World Bank (2011) Implementation Status and Results: Kazakhstan Forest Protection & Rehabilitation Project. http://www.worldbank.org/projects/P078301/forest-protection-reforestation-project?lang=en

# Chapter 6

## Summary

The Aral region of Kazakhstan belongs to the arid regions with annual rainfall of around 100 mm. Even under a severe water environment, a unique ecosystem of arid lands is the foundation for local livelihoods, through the provision of ecosystem services such as woods for fuel, animal fodder, regulation of land degradation and recreational benefits. However, regarding the wood resources management, two demands of conservation and resource utilization often have conflicting perspectives under an arid climate. Without appropriate resource management, the soil and vegetation in arid regions are highly vulnerable and susceptible to human activities. The study focused on the wood resource management in the Aral region of Kazakhstan, where the past environmental destruction and excessive logging have exposed a few important wood species to resource problems of consumption and conservation.

In Chapter 1, we outlined the historical context leading to the current resource problem and describes the research approach and objectives, where social surveys were conducted with residents and authorities, and based on them, provided a possible way planned reforestation from the technical aspect.

In Chapter 2, general information of the study area such as climate, vegetation, location of the survey district and population statistics, was described. Also, description of the black saxaul plot that the survey was conducted was given.

In Chapter 3, the current situation of the use of alternative fuel timber and logging sites was clarified by questionnaires and interviews following a review of political measures and issues in this region. The survey showed a dilemma between conservation of the wood resources and livelihoods in the region. Tamarisk is likely to become endangered in the future as a result of excessive demand as the number of households that use wood has being increasing in the target district. The implementation of an assessment of logging sites and the establishment of a feedback system involving local communities are recommended. Although black saxaul has considerable potential in quality for supporting local fuelwood demands, this species requires careful management, because the residents' potential preference to black saxaul was significantly high. These results suggested that technical improvement in planting black saxaul was the urgent issue for the future risk management to recover a conventional relation between local living and ecosystem services, leading to avoiding the excessive demand for tamarisk as well as securing the conservation policies in the region.

Chapter 4 reports on Soil properties that determine the mortality and growth of *Haloxylon aphyllum*. Technical improvement is urgent to strengthen the resilience of the ecosystem that provides fuelwood for local residents, owing to the current high dependence on one alternative species. However, overall results from the recent decade are not promising with a very low survival rate of seedlings. Despite the administrative efforts at reforestation, the reasons for low survival have not yet been clarified. The results from soil chemical and physical analysis and topographic surveys reported that the 100 cm of sand sediment can be the key for black saxaul seedlings to take root, although little attention has been paid to the subsoil condition so far. Technical improvement in site selection based on soil properties will ensure the planned management through the increase in survival rate on reforestation.

In Chapter 5, a whole discussion was made. Although the results of this research gained suggestion to achieve both conservation project and life guarantee in future forest resource management, at the same time, as a big problem remained, the weak governance system on management responsibility. The vulnerability of this system will trigger a new environmental problem even if the benefit sharing in the conservation projects is brought to the local society along with technical improvement.

## Acknowledgement

I would like to thank the residents and organizations in the Aral region for their participation in the surveys who supported my work and helped me get results. I would like to deeply appreciate Dr. Konstantin Pachikin of the Research Institute of Soil science and Agrochemistry in Kazakhstan and Ms. Maira Kussainova of Kazakh National Agrarian University for their strong support on several field surveys in Kazakhstan. I am grateful to all the members of Soil Science Laboratory and Terrestrial Ecosystems Management Laboratory at Kyoto University for their patience and support in overcoming numerous obstacles I have been facing through my research. I also deeply appreciate Dr. Norio Ishida, a president of the NGO 'People's Institute of Environment', for his strong support and advice in my Kazakhstan research and other many fruitful experiences in field work.

I would like to express my sincere gratitude to my supervisor Professor Dr. Shinya Funakawa. This dissertation would not have been completed without his constructive comments and strong administrative supports. I am grateful to Dr. Hitoshi Shinjo, Dr. Tetsuhiro Watanabe and Dr. Yuki Okamoto. Their constructive and insightful suggestions have always motivated me to accomplish this work. Similarly, I would like to express my gratitude to Ms. Haruyo Hoshino and Ms. Reiko Okuda for continued support in various phases of my PhD. student life in Kyoto University.

I am also grateful to Professor Dr. Izuru Saizen of Graduate School of Global Environmental Studies, for being a reviewer my dissertation and providing constructive comments.

In addition, Professor Dr. Kaoru Imamura of Nagoya Gakuin University has strongly supported and encouraged me on my research. I would like to express my sincere gratitude for her warm support. I would also like to appreciate the help from Professor Dr. Eiji Nawata of Graduate School of Agriculture in Kyoto University. The possibility of my academic career was left open thanks to his supportive effort.

Last but not the least, I would like to thank my family: my parents and my sisters for supporting me spiritually throughout writing this thesis and my life in general. A special thank goes to my husband for his support and undiminished understanding. He always believed the accomplishment of this work and kept me calm and positive during the research. In the end, I would like to thank all persons whom I could not mention here.

Kayo Matsui

# Сауалнама

Менің есімім – Мацуй Каё. Мен Жапонияның Киото Универсиетінде қоршаған ортаны зерттеумен айналысатын докторантура студентімін. Осы зерттеу жұмысында Арал өңіріндегі отын және су ресурстарының өзгерісі, осы өңірдің қоршаған орта жағдайы, сексеуіл көшеттерін отырғызуға қатысты жергілікті халықтың ой-пікірін білгім келеді. Сол себепті төмендегі сұрақтарға жауап беруіңізді өтінемін.

＊Сізге аты-жөніңізді жазу қажет емес.

＊Анкета нәтижесі тек ғылыми-зерттеу мақсатында қолданылады.

＊Барлық сұрақтарға жауап берген соң беттерді тағы бір рет қайталап оқыңыз. Содан кейін осы бланкті қайтарып беріңіз.

Бланк толтырылған күнді қойыңыз：«　　» ______________ 2015 жыл

## 【СІЗ ТУРАЛЫ АҚПАРАТ】

A **Жынысы** 1. Әйел 2. Еркек

B **Жас мөлшеріңізді көрсетіңіз** 1. 20-29 2. 30-39 3. 40-49 4. 50-59 5. 60-69 6. 70-тен жоғары

C **Мамандығыңыз қандай ?** 1) Үй шаруасында 2) Студент 3) Қызметкер 4) Балықшы 5) Мал шаруашылығы 6) Медицина саласы 7) Саудагер 8) Зейнеткер 9) Басқа (__________________________)

D **Осы ауылда тұрғаныңызға қанша жыл болды? _____**жыл

E **Осы ауыл тумасы емес респондентке сауал.**

Туған жеріңіздің атын жазып беріңіз (__________________________________________)

F **Жанұя құрылымын көрсетіңіз. Сізге қатысты жердің астын сызыңыз. Жанұя бірнеше адамнан тұрса жанына әрқайсысының санын жазыңыз. Мысалы, екі ұлыңыз болса, ұл 2 деп жазыңыз.**

1. Ата 2. Әже 3. Әке 4. Ана 5. Аға 6. Әпке

7. Іні 8. Қарындас 9. Ұл 10. Қыз 11. Немере 12. Жиен

## 【Үй жануарлары туралы】

G **Қолыңыздағы мал санын айтып беріңіз.**

1. Қой-ешкі____бас 2. Сиыр____бас

3. Жылқы____бас 4. Түйе____бас

H **Қашаннан бері қолыңызда мал ұстап келесіз?**

1. Қой-ешкі ___ жылдан бері
2. Сиыр ___ жылдан бері
3. Жылқы ___ жылдан бері
4. Түйе ___ жылдан бері

## 【Отын ресурстары туралы】

I **Күнделікті тұрмыстағы қолданылатын су, газ, көмір және ағаш отынының жылдық тұтыну мөлшері туралы айтып беріңіз.**

Бір айға қолданылатын су мөлшері бағасы қанша? ______________ теңге

Бір жыл ішінде қолданылатын газ баллон саны қанша? ___ баллон

Жылына қолданылатын ағаш отыны _____ машина (1 машина 8м$^3$)

Жылына қолданылатын көмір отыны ____тонна

J **Төменде Кеңес үкіметі ыдыраған 1991 жылдан бері 2006 жылға (сексеуілді шабуға тиым салынған) дейінгі аралықтағы ағаш отыны қолданысы туралы айтып беріңіз.**

J-1 **Осы жылдар аралығында қандай ағаш отынын қолданып келдіңіз? Төменде таңдаған жауаптың астын сызыңыз.**

1. Сексеуіл  2. Жыңғыл  2. Жүзгін  3. Қарабарақ  4. Басқа (  )

J-2 **Жоғарыда таңдаған ағаш отынын қандай мақсатта қолдандыңыз? Төменде таңдаған жауаптың астын сызыңыз.**

1. Қыста үйді жылыту үшін
2. Тамақ жасау үшін
3. Нан пісіру үшін
4. Басқа (  )

K **Газбен көмір отынын қай жылдардан бері қолданып келесіз? Төменде қолданған жылдардың астын мысалға қарап отырып сызып, көрсетіп беріңіз.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Мысалы** | газ : | 1960 | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 |
| | көмір : | 1960 | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 |

Газ : 1960 1970 1975 1980 1985 1990 1995 2000 2005 2010

Көмір : 1960 1970 1975 1980 1985 1990 1995 2000 2005 2010

**【Арал өңірінің қоршаған ортасы туралы】**

L **Осы өңірдегі қоршаған орта мәселелері туралы пікіріңізді білдіріңіз. Әр мәселеге 1 (аса өзекті емес) ~ 5 (өте өзекті) аралығында баға беріп, ішінен біреуін қоршауға алыңыз.**

| | Күрделі мәселелер | Аса өзекті емес | Өзекті емес | Орташа | Өзекті | Өте өзекті |
|---|---|---|---|---|---|---|
| a | Шаң-тозаңның ұшуы | 1 | 2 | 3 | 4 | 5 |
| b | Тұздың ұшуы | 1 | 2 | 3 | 4 | 5 |
| c | Құмның көшуі | 1 | 2 | 3 | 4 | 5 |
| d | Жасыл өсімдіктердің аз болуы | 1 | 2 | 3 | 4 | 5 |
| e | Асыра шабудан ағаш санының азаюы | 1 | 2 | 3 | 4 | 5 |
| f | Қоқыс-қалдықтардың болуы | 1 | 2 | 3 | 4 | 5 |
| g | Су ластануы | 1 | 2 | 3 | 4 | 5 |
| h | Судың азаюы | 1 | 2 | 3 | 4 | 5 |

**【Ағаш отыны ресурстары туралы】**

M **Сексеуіл мен жыңғылдың ағаш отыны ретіндегі сапасы туралы өз ой-пікіріңізді білдіріңіз. Әр мәселеге 1 (өте төмен) ~ 5 (өте жоғары) аралығында баға беріп, ішінен біреуін қоршауға алыңыз.**

M-1 **Сексеуіл сапасы туралы**

| | Өте төмен | Төмен | Орташа | Жоғары | Өте жоғары |
|---|---|---|---|---|---|
| Жеңіл бүктеледі | 1 | 2 | 3 | 4 | 5 |
| Тасымалдауға ыңғайлы | 1 | 2 | 3 | 4 | 5 |
| Тез жанады | 1 | 2 | 3 | 4 | 5 |
| Қызуы жоғары | 1 | 2 | 3 | 4 | 5 |
| Қызуы ұзаққа сақталады | 1 | 2 | 3 | 4 | 5 |
| Түтіні көп | 1 | 2 | 3 | 4 | 5 |
| Күлі көп | 1 | 2 | 3 | 4 | 5 |

M-2 **Жыңғыл сапасы туралы**

| | Өте төмен | Төмен | Орташа | Жоғары | Өте жоғары |
|---|---|---|---|---|---|
| Жеңіл бүктеледі | 1 | 2 | 3 | 4 | 5 |
| Тасымалдауға ыңғайлы | 1 | 2 | 3 | 4 | 5 |
| Тез жанады | 1 | 2 | 3 | 4 | 5 |
| Қызуы жоғары | 1 | 2 | 3 | 4 | 5 |
| Қызуы ұзаққа сақталады | 1 | 2 | 3 | 4 | 5 |
| Түтіні көп | 1 | 2 | 3 | 4 | 5 |
| Күлі көп | 1 | 2 | 3 | 4 | 5 |

M-3 **Ағаш отынының бағасы туралы пікіріңізді білдіріңіз. Егер сексеуілді сатып алған жағдайда, 1 машина сексеуіл отыны бағасы қанша болу керек деп санайсыз.**

1 машина ________________ тенге

N **Қазір сексеуілді шабуға тиым салуға байланысты сексеуілді пайдалана алмау туралы пікіріңіз қандай? Әр мәселеге 1 (өте төмен) ~ 5 (өте жоғары) аралығында баға беріп, ішінен біреуін қоршауға алыңыз.**

| | Өте төмен | Төмен | Орташа | Жоғары | Өте жоғары |
|---|---|---|---|---|---|
| Сексеуілді қолдана алмау ыңғайсыз | 1 | 2 | 3 | 4 | 5 |
| Сексеуілге тиым салу маңызды | 1 | 2 | 3 | 4 | 5 |
| Сексеуілдің орнына жыңғыл бар | 1 | 2 | 3 | 4 | 5 |
| Сексеуілдің орнына көмір бар | 1 | 2 | 3 | 4 | 5 |
| Тиымды алып тастағанын қалаймын | 1 | 2 | 3 | 4 | 5 |

O **Сексеуіл ағашының саны жақын жылдарды едәуір ұлғайып, Қазақстан үкіметі сексеуілді шабуға тиымды алып тастаса, сексеуілді отынға қолданасыз ба? Ой пікіріңзді білдіріңіз.**

1. Ия, қолданамын (→O-1ге көшіңіз)
2. Жоқ, қолданбаймын (→O-2ге көшіңіз)
3. Қалыс қаламын

O-1 **Ия, қолданамын жауабын таңдаған респондентке сауал. Сексеуілді қолдану себебін айтып беріңіз. Әр мәселеге 1~5 аралығында баға беріп, ішінен біреуін қоршауға алыңыз.**

| | | Аса келіспеймін | Келіспеймін | Орташа | Келісемін | Өте келісемін |
|---|---|---|---|---|---|---|
| a | Сексеуіл ағаш отыны ретінде қызуы өте жоғары | 1 | 2 | 3 | 4 | 5 |
| b | Сексеуілді сатуға болады | 1 | 2 | 3 | 4 | 5 |
| c | Сексеуіл көмірге қарағанда арзан | 1 | 2 | 3 | 4 | 5 |
| d | Жыңғылдың сан мөлшері азюы алаңдатады | 1 | 2 | 3 | 4 | 5 |

O-2 **Жоқ, қолданбаймын жауабын таңдаған респондентке сауал. Сексеуілді қолданбау себебін айтып беріңіз. Әр мәселеге 1~5 аралығында баға беріп, ішінен біреуін қоршауға алыңыз.**

| | | Аса келіспеймін | Келіспеймін | Орташа | Келісемін | Өте келісемін |
|---|---|---|---|---|---|---|
| a | Сексеуілді отынға қолдану керек емес | 1 | 2 | 3 | 4 | 5 |
| b | Сексеуілдің бағасы қымбат | 1 | 2 | 3 | 4 | 5 |
| c | Сексеуілге қарағанда жыңғыл қолданысқа жеңіл | 1 | 2 | 3 | 4 | 5 |
| d | Жыңғылдың саны өте көп | 1 | 2 | 3 | 4 | 5 |
| e | Сексеуілдің сан мөлшері азаюы алаңдатады | 1 | 2 | 3 | 4 | 5 |
| f | Сексеуілді көгалдандыруға қолданған жөн | 1 | 2 | 3 | 4 | 5 |

P **Қазір, осы өңірде жыңғыл саны қанша бар деп ойлайсыз? Төменде таңдаған жауаптың астын сызыңыз.**

1. Өте көп
2. Көп
3. Орташа
4. Аз
5. Өте аз

**Сексеуіл көшеттерін отырғызу туралы】**

Q **Арал өңірінде сексеуіл көшеттерін отырғызуға қатысты ой-пікіріңізді білдіріңіз. Төменде таңдаған жауаптың астын сызыңыз.**

1. Келісемін (→Q-1ге көшіңіз)
2. Келіспеймін (→ келесі беттегі Q-2ге көшіңіз)
3. Қалыс қаламын

Q-1 **Келісемін жауабын таңдаған респондентке сауал. Әр мәселеге 1~5 аралығында баға беріп, ішінен біреуін қоршауға алыңыз.**

| | | Аса келіспеймін | Келіспеймін | Орташа | Келісемін | Өте келісемін |
|---|---|---|---|---|---|---|
| a | Құм көшуін тоқтатуға көмегі тиеді | 1 | 2 | 3 | 4 | 5 |
| b | Шаң-тозаң, тұз ұшуын тоқтатады | 1 | 2 | 3 | 4 | 5 |
| c | Желді тоқтатады | 1 | 2 | 3 | 4 | 5 |
| d | Айналаның көркі жақсарады | 1 | 2 | 3 | 4 | 5 |
| e | Ауа тазарады | 1 | 2 | 3 | 4 | 5 |
| f | Үкіметтің қоршаған ортаға қатысты іс-шараларына көмегі тиеді | 1 | 2 | 3 | 4 | 5 |
| g | Сексеуіл саны көбейсе отынға қолдануға болады | 1 | 2 | 3 | 4 | 5 |
| h | Су құюдың қажеті жоқ | 1 | 2 | 3 | 4 | 5 |
| i | Сексеуіл саны аз | 1 | 2 | 3 | 4 | 5 |
| j | Сексеуіл осы өңірге бейімделген | 1 | 2 | 3 | 4 | 5 |

Q-2 **Келіспеймін жауабын таңдаған респондентке сауал. Әр мәселеге 1~5 аралығында баға беріп, ішінен біреуін қоршауға алыңыз.**

| | | Аса келіспеймін | Келіспеймін | Орташа | Келісемін | Өте келісемін |
|---|---|---|---|---|---|---|
| a | Сексеуілдің өсуіне уақыт керек | 1 | 2 | 3 | 4 | 5 |
| b | Суғару үшін уақыт, қаржы, эенергия, адам күші қажет | 1 | 2 | 3 | 4 | 5 |
| c | Көшеттерді отырғызғанмен отынға пайдалана алмаймын | 1 | 2 | 3 | 4 | 5 |
| d | Қоршаған ортаның жақсаруына ықпалы байқалмайды | 1 | 2 | 3 | 4 | 5 |
| e | Сексеуіл саны табиғи түрде ұлғаяды | 1 | 2 | 3 | 4 | 5 |
| f | Сексеуіл болмаса да аса қиналмаймын | 1 | 2 | 3 | 4 | 5 |

**Сауалнама осымен аяқталды. Сізге Үлкен рахмет!**

## List of Figures and Tables

### Figures



### Tables

## Publications

Chapter 3

Matsui Kayo and Akhapov Yerlan (2015) Арал өңіріндегі сексеуіл отырғызу мен ағаш отыны ресурсының қолданысы: Қаратерең ауылдық округінің мысалында, *Вестник КазЭУ/ КазЭУ Хабаршысы* 2015 год, №4 (105), pp.19-29 (in Kazakh) "Saxaul planting and use of wooden resource in the Aral region: A case study in Karateren rural district"

Kayo Matsui, Yerlan Akhapov, Shinya Funakawa (2017) Management of wood resources: A dilemma between conservation and livelihoods in a rural district in the Aral region, *Energy for Sustainable Development,* 41C, 121-127.
DOI: 10.1016/j.esd.2017.08.010

Chapter 4

Kayo Matsui, Tetsuhiro Watanabe, Maira Kussanova, Shinya Funakawa (2018) Soil properties that determine the mortality and growth of Haloxylon aphyllum in the Aral region, Kazakhstan, *Arid Land Research and Management*, 33 (1), 37-54.
DOI: 10.1080/15324982.2018.1496187