Title

Management of wood resources: A dilemma between conservation and livelihoods in a rural district in the Aral region

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Running title

Management of wood resources in a rural district

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- The study focused on economically and environmentally important tree species, black saxaul (*Haloxylon aphyllum*) and tamarisk (*Tamarix hispida*)
- Tamarisk is likely to become endangered in the future as a result of excessive demand
- The residents' potential preference to black saxaul was significantly higher than tamarisk
- Although black saxaul has considerable potential for supporting local fuelwood demands, this species requires careful management
- The implementation of an assessment of logging sites and the establishment of a feedback system involving local communities are recommended

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Keywords: Black saxaul (*Haloxylon aphyllum*); Tamarisk (*Tamarix hispida*); the Aral Sea; Fuelwood; Residents' perceptions; Forest management

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Abstract

This study focused on black saxaul (*Haloxylon aphyllum*) and tamarisk (*Tamarix hispida*), which are economically and environmentally important trees in one of the most arid parts of the Aral region. Black saxaul is the main local fuelwood species. However, its extraction was banned after it became critically endangered in the 1990s. Planting this species is now regarded as essential for rehabilitating the Aralkum Desert in light of the Aral Sea crisis. Tamarisk is another fuelwood species that supports local livelihoods. We administered questionnaires among residents in Karateren district and conducted interviews with some residents and with policymakers responsible for regulating forest management. The findings revealed a significantly higher preference for black saxaul than for tamarisk among residents, with a high potential demand for the former. Moreover, some residents observed a decrease in tamarisk biomass, which could accelerate as a result of constant population growth in the study district. We recommend conducting an assessment of logging sites and establishing a feedback system involving local communities to develop risk management that can address future shortages in wood supplies and over logging. While political decision making should also consider the uneven preferences of residents of this region for fuelwood species.

1. Introduction

The Aral Sea was previously the fourth largest inland lake in the world. However, commencing from the 1960s, large-scale and inefficient irrigation has occurred in the upper river basin leading to a decrease in the water volume flowing into the Aral Sea and causing its shrinkage [1, 2, 3, 4]. Consequently, an extensive man-made desert has been created along the dry seabed, becoming the main source of salt dust storms [5, 6], although there is room for discussion to scientifically prove the exact extent of damage on the region [7]. This human-induced disaster has led to severe ecosystem destruction, regional climate change, as well as health and socioeconomic problems within local populations [2, 3].

Severe sand storms, entailing high salt levels have become common occurrences, impacting the livelihoods of local residents of this region [8, 9]. To alleviate the damage caused by increased amounts of sand, and to improve the region's vegetation, the government of Kazakhstan and international organizations such as the World Bank and the United Nations Development Programme have implemented large-scale reforestation projects involving a native tree species, black saxaul (*Haloxylon aphyllum* (Minkw.) Iljin), which has a high degree of tolerance for aridity and salinity [2, 10, 11, 12].

Black saxaul has long been an essential fuelwood resource for local residents. However, massive deforestation in the 1990s led to the depletion and endangerment of black saxaul, which was threatened with extinction [6, 10]. Consequently, commencing from 2004, logging of saxaul species has been completely prohibited in the Aral region [13]. The use of black saxaul has been replaced by tamarisk (*Tamarix hispida*), another tree species as a major source of fuelwood (local forest office). Because the arid climate of the Aral region permits very limited vegetation, human activities can have a significant impact on the environment of this region. Therefore, policymakers need to ensure a balance in management priorities relating to the conservation and consumption of fuelwood species in the region. However, in recent decades, there have been few studies conducted on fuelwood consumption and forest management at the level of local communities. 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.

Residents of the study district have suffered as a result of the human-induced disaster relating to the Aral Sea crisis and the decline of the regional economy during the post-Soviet era [14]. They have eked out a living in one of the most severely degraded regions where there is little hope of recovering the original ecosystems. The focus has instead been on rehabilitation through planting [15, 16]. Further, because expansion of the vegetation is limited by the extreme arid climate [17], biomass is easily endangered by external pressures. Thus, effective governance relating to the

consumption of fuelwood is paramount in this region. This study's objective was to shed light on the situation regarding the consumption of these resources and to determine what countermeasures should be taken by local authorities.

2. Materials and methods

2.1. Study site

The study site was Karateren District (45°58'54" N and 61°02'50" E), Kazakhstan, which is located along the former seashore at the estuary of the Syr Darya River in the Aral region (Fig. 1). According to statistics available for the Aral region, the population of this district was 1,677 in 2015, and was distributed across the following villages: Kune Karateren, Zhana Konys, Kol Zhaga, and Tastak. There were about 240 households located within the central area comprising Zhana Konys and Kol Zhaga. Kune Karateren and Tastak had 27 households and 35 households, respectively. 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 [18]. With the exception of 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.

2.2. Data collection

Following a preliminary survey conducted in the fall of 2014, a 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 [19, 20, 21]. 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 Kazak language, which is the main language in the region. The collected data were translated into English

after completing the survey.

2.3. 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).

2.4. 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.

2.5. 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.

2.6. 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.

2.7 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. Results

3.1. Description of the respondents

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

3.2. 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 Djingil), *Calligonum leucocladum* (known locally as Dzhuzgun), and *Halostachys caspica* (known locally as Karabarak) [22]. 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 amount of woods for a sauna was extremely small so that the owners did not secure wood but were managing 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.

3.3. 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).

3.4. 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 ($p < 0.01$).

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. 2 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.

3.5. Intention to use black saxaul as fuelwood

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 (Fig. 3a). 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 (Fig. 3b). 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. This question was investigated further, and in more detail, within the questionnaire used for the main survey, as shown in Figs. 4. 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) (Fig. 3a). Among the items associated with respondents' non-use of black saxaul, the lowest level of agreement (51%) occurred for (d) (Tamarisk is abundant) (Fig. 3b).

3.6. Opinions about the black saxaul logging restriction

Fig. 4 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

253 (72%) was found for (b). Moreover, many of the respondents took a long time to answer this
254 question and were reluctant to give a clear answer (agree or disagree) for items (c) and (d), resulting
255 in the highest ratios of “no opinion” for these items (30% and 24% respectively).
256
257 **3.7. Perceptions of tamarisk biomass**
258 When queried about their perceptions regarding tamarisk biomass, 59% of the respondents felt
259 that biomass was “normal” and that there was neither an increase nor a decrease, 24% felt that the
260 amount of biomass was small or very small, and 17% perceived the amount of biomass to be large or
261 very large (Fig. 5). During open-ended interviews held with residents, some respondents expressed
262 concern that the number of old trees had decreased recently, and consequently they had no choice
263 but to cut young trees to meet their demands. However, the view of the director of the forest office
264 was that the rule permitting residents to cut only old trees in logging sites was being effectively
265 applied in this region. Moreover, the director suggested that the fast-growing tamarisk supported
266 fuelwood demands in the region.
267
268
269 **4. Discussion**
270 Because arid regions are particularly vulnerable to the impacts of human activities, there is a need
271 for carefully designed and implemented forest management in such regions [21, 23, 24]. Because
272 vegetation is absolutely scarce in the dryland ecosystems, fuelwood is valuable for sustaining
273 people’s livelihoods in drylands [25, 26, 27]. Especially in the remote areas where the energy
274 transport from the outside is inefficient and costive, a sustainable usage of local wooden resources
275 has traditionally been the most preferable way. Therefore, local wood resources under careful
276 management needs to be seriously considered once the balance of ecosystems including local
277 livelihoods is endangered. This is also the case in the Aral region [28].
278 Through the observations in preliminary survey, we confirmed that coal and tamarisk
279 are the fuel resources used for the house heating system, and these materials are
280 alternative to each other. This was also statistically supported from the quantitative
281 data collected in the main survey. The results of the study indicated a correlation between the
282 consumption of gas and family size, because gas is used for cooking. However, there was no
283 correlation found between the consumption of tamarisk and coal and family size, because these
284 materials are used for house heating (Table 2). Moreover, the findings revealed that not everybody
285 could afford to buy coal. Further, even among households that purchased coal, the main fuel used
286 was tamarisk wood and not coal. Consequently, whereas gas could replace wood used for cooking, it
287 could not replace wood used for heating houses. This is because the heating system is optimized for
288 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).

As shown in Fig. 5, 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 [29, 30, 31]. Further, low combustion efficiency results in high consumption, which, in turn, leads to increased collection of fuelwood from forests [32]. The findings on local residents' attitudes and the reasons for these attitudes, which have a bearing on the future use of black saxaul (Figs. 4), also support the conclusion that residents are conscious of the amount of tamarisk biomass, as discussed in section 3.5. 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 [33, 34, 35].

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. 2 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. 3a). 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. 3b). 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.

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.

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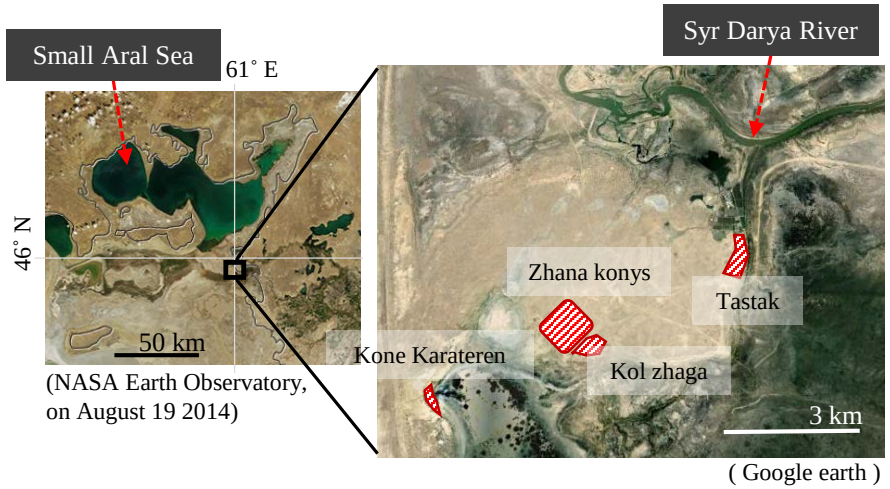

Fig. 1. Study site

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).

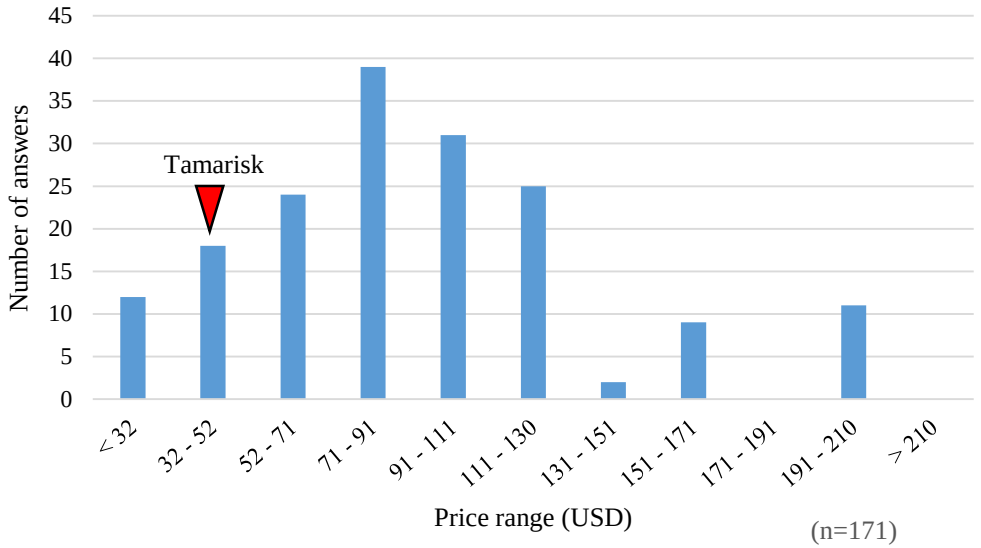

Fig. 2. Hypothetical price of a truck of black saxaul
The number of respondents who answered the each range of price for a truck of saxaul were counted. The red arrow is the actual price range of a truck of tamarisk ($6m^3$). The unit is USD calculated by the average rate of Kazakhstan currency Tenge to USD during survey period. (1USD = 252 Tenge)

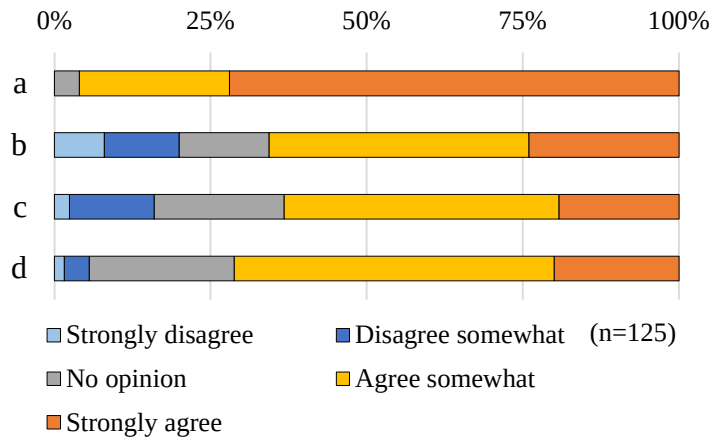

Fig. 3a. Rate distributions of evaluation in each reason for 'Yes, I will use'
68% of respondents (n = 192) answered affirmatively when asked whether they would use black saxaul if the restriction was lifted. Items: a. Fire power is strong; b. Saxaul can be sold; c. Saxaul is cheaper than coal; d. I'm worried of the decrease of tamarisk

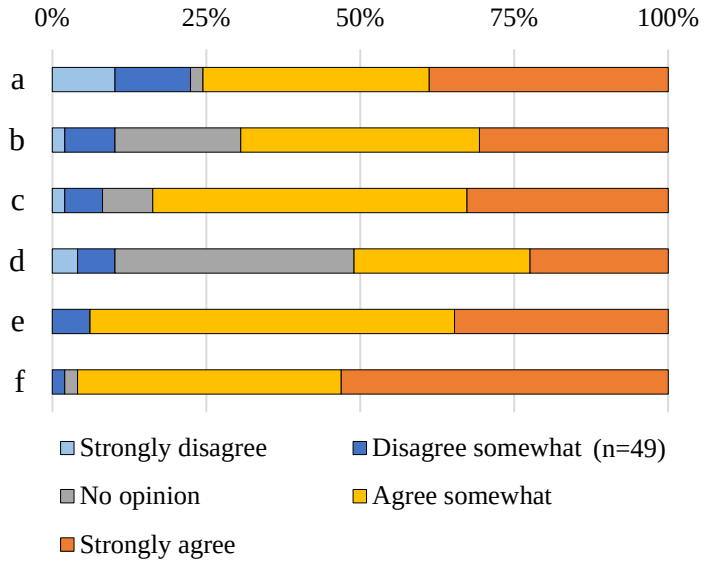

Fig. 3b. The evaluation of the reason items for 'No, I won't use '
29% of respondents (n = 192) answered negatively when asked whether they would use black saxaul if the restriction was lifted. Items: a. saxaul is not needed for fuel; b. saxaul is expensive; c. Tamarisk should be used instead of saxaul; d. The number of tamarisk is large; e. I'm worried of the decrease of saxaul; f. Saxaul should be used for plantation

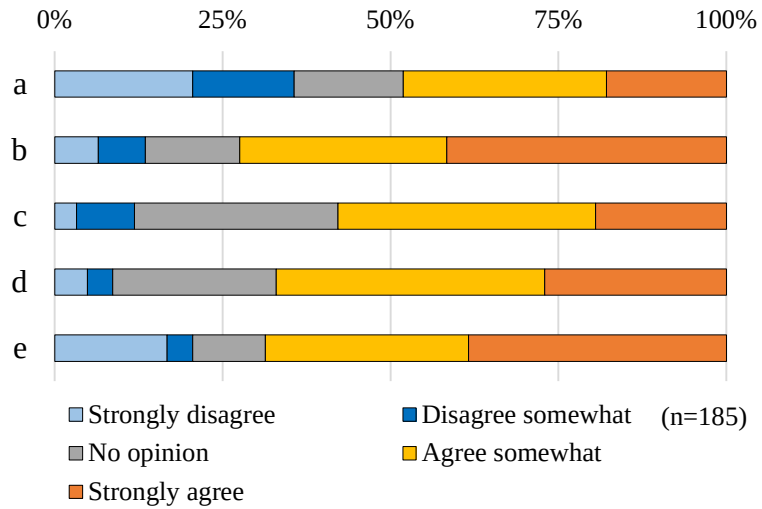

Fig. 4. Residents' opinions toward the restriction of logging black saxaul
Items: a. It is uncomfortable that saxaul is not available.; b. The restriction of saxaul is important.; c. Tamarisk can substitute for saxaul.; d. Coal can substitute for saxaul.; e. I want the restriction to be lifted.

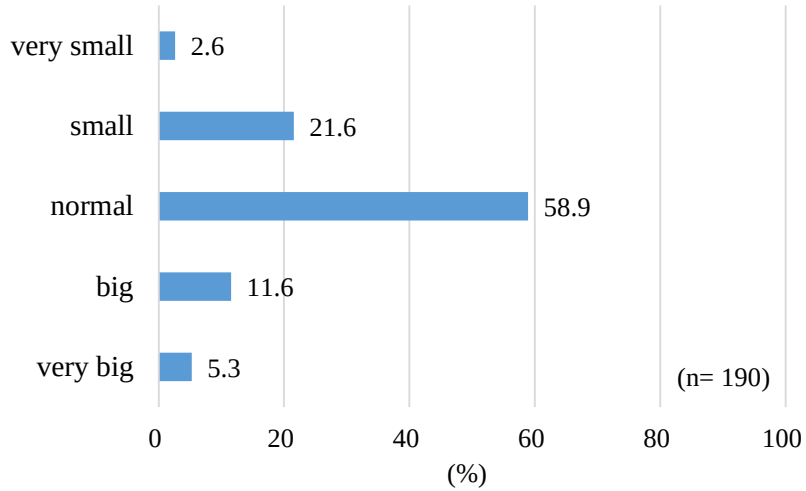

Fig. 5. Recognition of the tamarisk biomass

Table 1
Component of the respondents

Date	2015. Sep 1st -18th
Households	192 (64 %)
Sex	
female	90 (46.9%)
male	102 (53.1%)
Age	
20s	50 (26.2%)
30s	56 (29.3%)
40s	35 (18.3%)
50s	31 (16.2%)
over 60s	19 (9.9%)
not answered	1 (0.5%)

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 3.2 USD/27L
Annual consumption (Average ±sd)	13.1±4.8 m^3	2.3±1.4 t	574±240 L
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

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

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.