

Reply to Anonymous Referee #1

Comment 01:

“This article describes a success story for a huge human effort dealing with difficult environmental problems on one of the most challenging contexts for urban settlements on Earth. The paper presents the case for dust storms, a severe environmental problem limiting environmental quality in urban settlements in NW China, and the potential of urban protection forests to improve environmental services. The article explains the process of creation of the urban protection forest and its management with sufficient detail. A very brief survey and a superficial cost-benefit analysis are used, and results presented on their basis. The social and economic procedures are visibly weak; this might be justified by the limitations of the socio-political context in relation to lack of transparency and some additional difficulties, however, I consider the information presented is valuable material for the understanding of sustainability. In my opinion as a reviewer, the authors need to make many changes in the article to reach an acceptable academic standards, I would kindly suggest the author to rewrite the paper on the light of these comments, because the topic is extremely relevant. The list of suggestions below, including changes on the structure of the article, justify in my opinion the need of a MAJOR REVISION.”

Response:

Comment adopted. Changes required by Anonymous Referee #1 and the second referee Johannes K uchler have been integrated into the manuscript, which resulted in a major revision of the manuscript.

Changes in the manuscript:

For the single items of the major revision confer comments and responses listed below and in the separate reply to the comments of Johannes K uchler.

A.) General comments

Comment 02:

“The paper is grammatically well written but some sections are superfluous, I suggest the authors to remove the section “Synthesis” and potentially relocate any point found relevant on it and absent in other sections.”

Response:

Comment adopted.

Changes in the manuscript:

The section “Synthesis” has been removed. All those points that summarised results of the previous chapters have been deleted. The last paragraph of the section, analysing the payback period of the afforestation project, has been relocated into chapter “4.5 The perspective of the local economy”.

Comment 03:

“The authors spend too much sentences talking about what they could have done with better data or what they have not done because of its lack. This should be totally transformed, the case and information they provide is relevant enough. Please take all this “could” and “do not” and

limit them to one (long) paragraph in the discussion section, compiling the most relevant points and relate them to potential uncertainties in the outcome.”

Response:

Comment adopted. The respective part of the discussion section has been rewritten according to the indications of the referee.

Changes in the manuscript:

Citation from the revised chapter “5. Discussion and outlook”: “The paper describes the historic establishment and present functioning of the Kökyar Protection Forest with regard to its institutional frameworks and financial conditions. While the institutional frameworks of Kökyar I and II are described in satisfactory detail, Kökyar III adopts a differing, more market based approach, which has not been systematically documented yet. Further research must clarify the institutional functioning of Kökyar III, especially in comparison to Kökyar I and II. Concerning the description of the financial conditions, the *present* financial conditions of Kökyar have formerly not been subject to any publications, and the results of the respective calculations of this paper, being based on a socio-economic household survey comprising 19 leasing households and one additional expert interview with former leading staff of the state-owned organisations, are deemed to be rather rough estimates. Conducting interviews with actual leaders of the governmental organisations of Kökyar I and II and with large private landholders of Kökyar III would have been extremely desirable, however, under the present political tensions in Xinjiang and the resulting scepticism towards any type of social surveys, this seems hard to achieve.”

Comment 04:

“There is a general lack of mathematical language for the calculations used; I suggest you use 4-6 equations to complement the text describing how the values in tables are obtained, and especially describing the cost-benefit analysis (sic). This would clarify the paper.”

Response:

First part of the comment not adopted. The paper does not use any complex mathematical operation which would require to be explained in equations. Therefore, we do not see a lack of mathematical language. Additions of single cost items to total costs, single income items to total income, or single areas to total area, especially if there are many terms of the sum, can most clearly be presented in tables, as is done in the paper. The same is true for subtractions, e.g. of costs from incomes. The single items, of which the tables are composed, are mostly derived directly from the sources, as is explained in the text. As soon as the tables will be placed in the corresponding places in the text body, their readability will be further improved.

In some cases, we explain calculations in the continuous text. To give one example, in chapter “4.5 The perspective of the local economy”, we explain that working costs of 51.52 CNY/day multiplied with 180 working days/ha result in working costs of 9289 CNY/ha. We think, the clarity of this multiplication would not profit from the presentation of an equation and the necessary definitions ($wc/d * wd/ha = wc/ha$; where wc working costs, wd working days, ha hectares).

Second part of the comment adopted. In order to further clarify our analysis approach, the section describing cost-benefit analysis in chapter “2. Methods” has been enlarged and made more explicit.

Changes in the manuscript:

Regarding first part of the comment: none.

Regarding second part of the comment: citation from chapter “2. Methods”: “The effect of the Kökyar Protection Forest on the local welfare is summarised from the perspective of cost-benefit analysis. Cost-benefit analysis is an assessment method that “quantifies in monetary terms the value of all consequences of a policy to all members of society” (Boardman et al., 2011). In contrast to normal accounting practices applied by profit-oriented corporations to identify the most profitable investment opportunities, cost-benefit analysis is not limited to the monetary costs and benefits of the decision maker himself, but accounts for all marketable and non-marketable costs and benefits experienced by all individuals residing within the area of interest (Mishan and Quah, 2007). In a nutshell: a “benefit” is an increase in human wellbeing, and a “cost” is a reduction in human wellbeing (OECD, 2006). The term “net benefit” (i.e. subtraction of costs from benefits) therefore represents the overall societal welfare gain of a country or region. For the analysis conducted in this paper, the scope will be narrowed down to the local level, which means that downstream ecological costs caused by the Kökyar water consumption, although undoubtedly existent, will not be included. The focus will be set on marketable costs and benefits, while non-marketable effects will be verbally described (for more general information on cost-benefit analysis cf. Boardman et al., 2011).”

Comment 05:

“I think an interesting point to add would be a discussion in the decision of the species included in the artificial forest. Poplar consumes so much water, which you know how scarce it is in the area, and I would like to see a comparison with other species with lower water consumptions and similar potential for success, you could use modern academic studies with a biologic focus on transpiration for certain species and also contrast them with studies about traditional gardening in desert areas. The article approaches economically the topic with a superficial cost-benefit analysis, and present results that might be slightly optimistic due to a potential underestimation of what would be the labour and true water costs in a “free” economy. I am aware water prices almost never reflect their costs, but you could improve the paper elaborating on this and its interaction with the current results, could they change sign if these costs were properly accounted?”

Response:

Comment not adopted. The raised questions regarding tree species with lower water consumption and the true costs of water are, without any doubt, both interesting and relevant. Yet, they are out of the scope of this paper and should be subject to additional studies. In response to this comment, we clarified the focus of our paper – which actually is on institutional frameworks and financial conditions of the protection forest – by formulating a clear research question at the end of chapter “1. Introduction”. Furthermore, we made more explicit that the water prices stated in our paper do not reflect externalities, and we thematised the true water costs as an important future research field in chapter “5. Discussion and outlook”.

Changes in the manuscript:

Citation from chapter “1. Introduction” (research question): “This paper undertakes an exemplary analysis of the Kökyar Protection Forest under the following research question: Under which institutional frameworks and to which financial conditions can peri-urban shelterbelts be established and maintained?”

Citation from chapter “2. Methods”: “For the analysis conducted in this paper, the scope will be narrowed down to the local level, which means that downstream ecological costs caused by the Kökyar water consumption, although undoubtedly existent, will not be included.”

Citation from chapter “4.3 The perspective of the farmers”: “Irrigation water fees usually fall between 1125 CNY ha⁻¹ and 1275 CNY ha⁻¹. (These prices probably represent the costs of the irrigation infrastructure and operation; they do not reflect externalities.)”

Citation from chapter “5. Discussion and outlook”: “[...] the negative consequences of the Kökyar water consumption for downstream ecosystems need to be investigated. Principally, every drop of water diverted from Aksu River for the purpose of irrigating the Kökyar Protection Forest is detracted from its lower reaches and its main stem, the Tarim River. The improvement of the quality of life of Han-Chinese settlers in Aksu is thus bought by the resulting desiccation of downstream ecosystems and the consequent loss of downstream ecosystem services, which deprives local Uyghur farmers and herdsmen of their livelihoods. Internalising these downstream effects into the Kökyar water prices may challenge the net-benefit and the positive image of Kökyar Protection Forest.”

B.) Particular comments

Comment 06:

“Page 1676, line 16: The term pure seems too sensitive, if not inadequate, please change it.”

Response:

Comment adopted. “Pure” has been exchanged by “100%”.

Changes in the manuscript:

Citation from chapter “1.2 Geographic conditions of Aksu City”: “The composition of the population shifted from a nearly 100% autochthonous Uyghur society to a majority of foreign Han-Chinese settlers [...].”

Comment 07:

“Page 1676, line 8: Rumbaur et al. does not appear in the reference list, please check all for consistency.”

Response:

The paper by Rumbaur et al. is expected to be published in the same issue of Earth System Dynamics, but is not yet accepted. Therefore, the correct citation is not yet public. Our notification – “Rumbaur et al. (submitted to this issue)” – has been erased by the Copernicus editors.

Changes in the manuscript:

None. The citation will be inserted into the reference list as soon as it is known.

Comment 08:

“Page 1676, line 26: “there” should be “their”?”

Response:

Comment adopted; “their” is correct.

Changes in the manuscript:

Citation from chapter “1.3 The Kökyar Protection Forest”: “The four project periods and their corresponding areas were then chronologically labeled [...].”

Comment 09:

“Page 1678, line 14: “Other persons” should come with an explanation or rationale for their selection, it opens too much the possibilities and it is part of a weak aspect of this contribution, please clarify it.”

Response:

Comment adopted. The section about interview partners has been rewritten and explained in more detail. The rationale for their selection is self-explaining after we clarified the research question of the paper (cf. above).

Changes in the manuscript:

Citation from chapter “2. Methods”: “For information on the institutional processes and economic conditions of the state-owned organisations running the project, a semi-structured interview with the former head of the Forest Management Station was conducted. Other important information on the general circumstances all around the Kökyar Protection Forest were gathered by interviews with random Aksu citizens, a private farming consultant in Aksu, and a seasonal worker in the plantation. All these interviews were conducted between 2011 and 2012 (cf. Appendix A).”

Comment 10:

“Page 1678, line 20: See my comment above for could and don't. It also applies for “but without”.”

Response:

Comment adopted. This comment refers to chapter “2. Methods”, which has been rewritten in response to comment 04. In the course of this revision, the queried formulation became obsolete.

Changes in the manuscript:

The formulation “but without” has been taken out of the text. For citation cf. above, under comment 04.

Comment 11:

“Page 1679, line 14: You seem to use inconsistently spaces for figures, indicating thousands or millions? Please use commas for it, or be consistent with the selected format.”

Response:

Comment not adopted. We used to use commas in figures, but they have been replaced by spaces by the editors, according to the standards of Copernicus.

Changes in the manuscript:

None.

Comment 12:

“Page 1682, line 14: Tremendous and astonishingly are literary words, avoid such terms, your numbers make the point.”

Response:

Comment adopted. The words have been exchanged or avoided.

Changes in the manuscript:

Citations from chapter “3.5 Obligatory labour”: “Even so, the mobilisation of manpower reached very high levels [...]” “Although the areas of Kökyar III were to be developed and exploited by private investors, the system of calling ordinary citizens to compulsory labour was maintained [...]”

Comment 13:

“Page 1683, line 21: I seriously doubt there is a rational for your comment on “inferior work quality”; change it or provide rational and 2 citations of other works arguing similarly.”

Response:

Comment adopted. The queried sentence indeed contained an assumption that was not backed up by the sources. Since the content of the assumption was not vital to the thesis, it has been deleted.

Changes in the manuscript:

Citation from chapter “3.6 Initial investment costs”: “The coherence between those numbers can be taken as evidence that the cost calculation of Kökyar I is realistic, and that the costs of the past are transferrable to the present.” [following sentence deleted]

Comment 14:

“Page 1684, line 4: What does “apparently satisfactory” means in economic terms? Define or clarify.”

Response:

Comment adopted. The comment refers to chapter “4.1 The leasing system”, which gives a brief overview of the farming conditions of the leasers. The meaning of “apparently satisfactory” is repeated and explained in detail in chapter “4.3 The perspective of the farmers”. In response to the comment, we therefore could delete the queried sentence in chapter “4.1 The leasing system” without loss, thus preventing questions and misunderstandings.

Changes in the manuscript:

Citation from chapter “4.1 The leasing system”: “[...] regular irrigation water supply and some technical advice in fruit production (socio-economic household survey 2012). [sentence deleted] The leasers, in return, have to pay a substantial lease and an irrigation water fee.”

Comment 15:

“Page 1685, line 4: “Presently unknown” by the authors, somebody knows it in NW China, please clarify.”

Response:

Comment adopted. The corresponding sentence has been rephrased.

Changes in the manuscript:

Citation from chapter “4.1 The leasing system”. “The exact conditions under which the main tenants obtain land from the government have not been researched.”

Comment 16:

“Page 1688 , last sentence : The words organisation and organisational do not match very well in the same sentence.”

Response:

Comment adopted. The sentence has been rephrased.

Changes in the manuscript:

Citation from chapter “4.4 The perspective of the governmental organisations”: “The state-owned Water Management Station and Forest Management Station as subsidiary bodies of the Aksu River Drainage Area Management Department and the Aksu Prefectural Forestry Department are the organisational backbone of the system.”

Comment 17:

“Pages 1690, line 18: Mentioning an estimation of how much people work on the forest-orchard would help to understand your point about being a “prospering branch”.”

Response:

Comment adopted. An estimation of the number of jobs created by the project has been added.

Changes in the manuscript:

Citation from chapter “Yet, the invention of the orchard leasing system between the poplar shelterbelts gradually transformed it into a prospering branch of the local economy. The number of leasing households earning their livelihood in the orchards of Kökyar I can be estimated between 324 (Kökyar Annals Compilation Committee, 1996) and 454 (socio-economic household survey 2012). Extrapolated on the orchard area of Kökyar I, II, and III, these figures would allow an estimation of 1341 to 1880 farming households. In addition to these, a substantial number of jobs in the background organisation and in the poplar forests, and a smaller number of jobs for suppliers and commercial consumers can be assumed.”

Comment 18:

“Pages 1691, line 1-2: This dangerous assumption does not hold, many developing and transition countries keep farming labour as an additional source of income and in kind income, so you cannot really assume that other activities substitute the labour spent on the farm, rather than complementing it. Please modify and justify it in a proper way.”

Response:

Comment not adopted. The comment is based on a misunderstanding of the queried section. From the perspective of cost-benefit analysis, human labour (and every other means of production), no matter if paid or unpaid, involves costs for the society. The reasoning is as follows: if the human labour (or other means of production) had not been deployed to the considered project, it would have been deployed to other sectors of economy, where it would have contributed to societal welfare. But since it has been withdrawn from those other sectors, it reduces the capability of these sectors of increasing societal welfare. This decrease of societal welfare (in other sectors) has to be attributed to the considered project as so-called opportunity costs. Of course, this is an assumption, but it is a valid assumption and a standard assumption in order to define the opportunity costs of a project.

By the way, in the case of Kökyar, the farmland was created by the project, which means that the farmers were in fact withdrawn from other sectors of economy when they got settled in Kökyar.

Changes to the manuscript:

None.

Reply to Johannes Kuchler

A) General comment

(no responses required)

B) Specific comments

Comment 01:

"I propose a brief separate chapter/subchapter on the historicity of the project. It cannot be understood without referring to the national campaign / project of the Three North Shelterbelts. Shelterbelts provided by regular tree plantations have proven their usefulness under the conditions of 250 – 400 mm of annual rainfall, where they may survive with some auxiliary irrigation. But tree shelterbelts under totally arid conditions are a different matter, relying fully on irrigation. Thus one may ask: Did the national (political) macro-climate in favour for shelterbelts eventually prevent the examination of other more sustainable options to reduce the impact of dusty and sandy storms on the urban fabric? Also the switch to the forest leasing system has its national context as it was gradually introduced nation-wide since 1986."

Response:

First part of the comment adopted. A subchapter on the historicity of shelterbelts in China, including the Three North Shelterbelt, has been added.

Second part of the comment not adopted. The question of the national political macro-climate is out of the scope of this paper, as is the question of other potentially more sustainable policy options. In response to the comment and in order to prevent further misunderstandings of the scope, we clarified the focus of our paper – which actually is on institutional frameworks and financial conditions of the protection forest – by formulating a clear research question at the end of chapter "1. Introduction".

Third part of the comment adopted. The national context of the forest leasing system is outlined at the beginning of chapter "4.1 The leasing system".

Changes in the manuscript:

First part of the comment – citation from chapter "1.1 Shelterbelts in China": "More than 40% of China's total territory is characterised by arid and semi-arid climates. These drylands are predominantly located in the north and especially in the northwest of the country (Li et al., 2012). Shelterbelts have been seen as an effective instrument to fight negative influences from deserts and semi-deserts ever since the beginning of the People's Republic of China (Chokkalingam et al., 2006). The objectives of shelterbelts usually comprise environmental security (alleviating soil erosion, droughts, dust and sand storms, dry hot winds etc.) and economic development (increasing crop production, stockbreeding production, timber production and other forest products etc.). Structures and species compositions of the plantations alter according to site-specific conditions and purposes (Li et al., 2012, Chokkalingam et al., 2006). The biggest and globally best-known shelterbelt, the so-called Three-North Shelterbelt, is an overarching project that aims at increasing forest cover from 5% to 15% in an area of 4 069 000 km² that stretches over 13 province level administrative units all from the northwest to the northeast. Its establishment began in 1987 and is expected to last until 2050. 244 690 km² have been afforested so far (Li et al., 2012).

A special shelterbelt type has developed in the Tarim Basin in northwest China. The Tarim Basin is framed by the Tian Shan Mountains in the north and the Kunlun and Karakorum Mountains in the south and southwest, the Taklamakan Desert lying in the middle. Continental position,

precipitation shadow of the mountain ranges, and intense solar radiation form a hyper-arid climate. Oasis cities are located along the periphery of Taklamakan Desert, wherever rivers, running down from the surrounding mountains, provide sufficient water (cf. Fig. 1). Most of these cities, such as Korla, Būgūr, Aksu, Kashgar or Hotan, have experienced a rapid growth over the last decades, in the course of which natural greenbelts formed by native tree and shrub species have been eliminated by urban sprawl and agriculture. In order to protect the citizens from the influences of the surrounding desert lands, authorities of all these cities try to establish a special type of shelterbelt which could be labeled as peri-urban protection forest: broad greenbelts that optimally should surround the cities from all sides (Halik, 2003). The Kökyar Protection Forest in Aksu was one of the first of these.”

Second part of the comment – citation from chapter “1.3 The Kökyar Protection Forest” (research question): “This paper undertakes an exemplary analysis of the Kökyar Protection Forest under the following research question: Under which institutional frameworks and to which financial conditions can peri-urban shelterbelts be established and maintained?”

Third part of the comment – citation from chapter “4.1 The leasing system”: “In 1981, the State Council of the PR China had started promoting private forestry on a leasing basis by its “Resolution on Issues Concerning Forest Protection and Development” (*guanyu baohu senlin, fazhan linye ruogan wenti de jue ding*; for backgrounds cf. Delang and Yuan, 2015). In 1987, when the Kökyar afforestation work was still in the early stages, the Forest Management Station and Water Management Station reacted to this resolution and to the dire financial situation of their afforestation project, with the introduction of a leasing system that is fundamentally still in force today [...].”

Comment 02:

I also propose another separate chapter/subchapter on the definition of the meteorological event of dust and as well as on the specific local climatic, topographic, pedologic and hydrologic site conditions including earlier human impacts (overgrazing etc.).

Response:

Comment adopted. A section of the introduction, describing the geographic conditions of Aksu City, has been enlarged by the required information and upgraded to a separate subchapter (chapter “1.2 The geographic conditions of Aksu City”). Furthermore, chapter “3. The establishment of Kökyar Protection Forest” has been enlarged by a subchapter which describes the topographic, pedologic and hydrologic details of the Kökyar afforestation site (chapter “3.1 Site conditions”). Regarding earlier human impacts, we could not find information about the actual situation in Aksu, but we included general information about the usual human impacts around fast-growing oasis cities in the Tarim Basin.

Changes in the manuscript:

Citation from chapter “1.2 The geographic conditions of Aksu City”: “Aksu is a city of about 580 000 inhabitants of which 314 500 live in the urban core (Akesu Shi Renmin Zhengfu, 2012). It is the capital of Aksu Prefecture, lying in the west of China’s northwestern Xinjiang Uyghur Autonomous Region, close to the border of Kyrgyzstan. At a geographical position of 41°10’ north and 80°15’ east and at an altitude of 1100 m above sea level, it is situated on a long, slightly inclined slope between the Tian Shan Mountains in the north and the Taklimakan Desert in the south (cf. Fig. 1). The slope is traversed from northwest to southeast by the Aksu River, which is fed by snow and glacier melt water as well as rainfall from the nearby Tian Shan Mountains as introduced in Rumbaur et al. (submitted to this issue). The Aksu River formed a flat 10 km wide river valley with a steep cut bank of about 20 m height at its northeastern shore. The core of Aksu City lies exactly under the cut bank within the river valley, while today’s suburbs spread deeper into the valley and on the bank.

An annual evaporation rate of 1868 mm and annual precipitation of merely 75 mm indicate an extremely arid climate (Kökyar Annals Compilation Committee, 2006). Due to its location at the Aksu River, Aksu receives sufficient water to ensure agriculture, which places the city in a huge river oasis (ca. 1000 km², including Awat and Onsu County; Halik, 2003). However, the arid environment becomes very tangible whenever the regular hot and dry north winds blow down from the Tian Shan Mountains (Föhn effect). Maximum wind speeds are reached in springtime with 15 m s⁻¹ (Yoshino, 1992). Raising dust and sand from the barren areas north of the oasis, the north winds cause an annual average of 11.5 sand storm days (visibility less than 1 km) in Aksu City (Kökyar Annals Compilation Committee, 1996; also cf. chapter 3.2 Site conditions). The severe dust and sand storms of Aksu are blackening the sky, making respiration difficult, covering everything outside and inside houses with brown dust, inhibiting traffic, and disrupting public life (Aksu Prefectural Forestry Department and Kuqa Television Station, 2006; Aksu Prefectural Greening Committee, 2006; Aksu citizen interviews 2011)."

Citation from chapter "3.2 Site conditions": "The plantation site of the Kökyar Protection Forest lies in the north of Aksu City. It is a long stretch with an area of 1308 ha that extends 15.8 km from the Great Revolution Canal in the north to the suburbs of Aksu City in the south (cf. Fig. 2). It lies above Aksu City on an old fluvial terrace which slightly slopes from 1230 m above sea level in the north to 1125 m above sea level in the south. Most of its western boundary is defined by a steep cut bank of 20 m down to the Aksu River valley. The cut bank was canyoned by erosion gullies which extended deep into the area of later Kökyar, thus posing great problems for the levelling of the planting ground and construction of canals (Kökyar Annals Compilation Committee, 1996).

The fluvial terrace itself is composed of brown desert soil lying upon a gravel bed. The grain size at the surface changes from sandy gravel in the north to sandy silt and clay in the south. A high groundwater table and the regional extreme evaporation rate result in an average soil salinity of 2.87% and pH-values of 7.1 to 9.0. Before the afforestation, the soil was predominantly devoid of vegetation, with some areas being sparsely covered by *Alhagi spec.* and other herbaceous plants. The barren soil of the Kökyar plateau was regarded as a major source of wind erosion, thus contributing to the regular northerly dust and sand storms in Aksu City (cf. Fig. 2; Kökyar Annals Compilation Committee, 1996; Aksu Prefectural Forestry Department and Kuqa Television Station, 2006)."

Citation from chapter "1.2 Geographical conditions of Aksu City" (human impacts): "[...] the immigration-based growth and the economic development of oasis cities in the Tarim Basin usually was accompanied by degradation of the natural vegetation at the fringes of the oases, thus compromising their regulating ecosystem services and contributing to a factual aggravation of dust and sand problems (Halik, 2003). However, there is no literature on the specific situation around Aksu City."

Comment 03:

"The last paragraph of the text should be enlarged into a separate "Water" chapter discussing the water price issue (urbanites profiting from an almost non-existent agricultural water price). The authors mention the unbalanced distribution of water between upstream and downstream water users. This ethnic dimension of this imbalance – Han Chinese urbanites and farmers in Aksu versus Uighur farmers downstream – should also be mentioned.

Response:

Comment partially adopted. The question of the true costs of water is indeed highly interesting and relevant, yet, this very big topic is beyond the scope of this paper and should be treated in a separate paper. But in response to this comment, we clarified the focus of our paper – which actually is on institutional frameworks and financial conditions of the protection forest – by formulating a clear research question at the end of chapter "1. Introduction". Furthermore, in

chapter “4.3 The perspective of the farmers”, we made more explicit that the water prices stated in our paper do not reflect externalities, but rather reflect the costs of the irrigation infrastructure and its operation. Finally, we extended the section on externalities of water consumption in chapter “5. Discussion and outlook” and integrated the ethnic dimension of this conflict there.

Changes in the manuscript:

For citation of the research question cf. to comment 02, second part of the comment.

Citation from chapter “4.3 The perspective of the farmers”: “Irrigation water fees usually fall between 1125 CNY ha⁻¹ and 1275 CNY ha⁻¹. (These prices probably represent the costs of the irrigation infrastructure and operation; they do not reflect externalities.)”

Citation from chapter “5. Discussion and outlook”: “[...] the negative consequences of the Kökyar water consumption for downstream ecosystems need to be investigated. Principally, every drop of water diverted from Aksu River for the purpose of irrigating the Kökyar Protection Forest is detracted from its lower reaches and its main stem, the Tarim River. The improvement of the quality of life of Han-Chinese settlers in Aksu is thus bought by the resulting desiccation of downstream ecosystems and the consequent loss of downstream ecosystem services, which deprives local Uyghur farmers and herdsmen of their livelihoods. Internalising these downstream effects into the Kökyar water prices may challenge the net-benefit and the positive image of Kökyar Protection Forest.”

Comment 04:

“Technical terms should also be given (in footnotes or in an annex) in Chinese. For instance “compulsory labour” in contrast to “forced labour”.”

Response:

Comment adopted. The Chinese technical terms have been added in italic letters in brackets directly after their English translations. The chosen transliteration is Hanyu Pinyin. We have chosen to translate the Chinese term “yiwu laodong” as “compulsory labour” instead of “forced labour”, since “forced labour”, in the English context, rather is something that happens in penal camps. This type of labour would be referred to by a different Chinese word.

Changes in the manuscript:

For important technical terms, Chinese transliterations in Hanyu Pinyin have been added in italic letters in brackets directly after their English translations throughout the text. In order not to overburden this reply to the referee, just one exemplary citation from chapter “3.5 Compulsory labour” is given: “In order to meet the challenge of establishing huge forest areas in a poor financial situation, a legal regulation adopted in 1981 obliging all Chinese citizens to participate in “National Compulsory Afforestation Campaigns” (*quanmin yiwu zhishu yundong*) played a key role (Halik, 2003; interview 1). Based on this regulation, beginning from 1986 the Aksu Prefectural Party Committee called “all citizens, no matter which ethnicity, military or civilian” to participate in compulsory labour (*yiwu laodong*) on the fields, levelling the terrain, preparing the ground and planting trees with hard physical labour Kökyar Annals Compilation Committee, 1996; interview 1).”

C) Minor comments/questions and technical corrections

Comment 05:

“1675 On the one hand, the abstract is rather detailed and deserves some shortening, on the other hand it does not pose any guiding question. Would this be the question: ? To which extent

is it possible to identify costs and benefits of an erosion control project within the given political and administrative framework of a remote Chinese city?"

Response:

Comment adopted. The abstract has been shortened and the guiding question has been integrated.

Changes in the manuscript:

Citation from "Abstract": "The city of Aksu, situated at the northern fringe of the Taklimakan Desert in northwest China, is exposed to periodic severe dust and sand storms. In 1986, local authorities decided to establish a peri-urban shelterbelt plantation, the so-called Kökyar Protection Forest, with the aim to reduce dust and sand storm impacts on Aksu City by the regulating ecosystem services provided by the plantation. It was realised as a patchwork of poplar shelterbelts and orchards. The total area of the plantation reached 3800 ha in 2005. The Kökyar Protection Forest is exemplarily analysed to answer the following question: Under which institutional frameworks and to which financial conditions can peri-urban shelterbelts be established and maintained? The endeavour of planting the shelterbelt was made possible by the annual mass mobilisation of Aksu citizens, based on the Chinese regulation of the "National Compulsory Afforestation Campaigns". Establishment costs amounted to ca. 60 000 CNY ha⁻¹ (ca. 10 000 USD ha⁻¹). Permanent maintenance of the plantation is facilitated by leasing orchard plots to private fruit farmers. From the perspective of the local economy, annual farming net benefits generated by Kökyar fruit farmers more than compensate annual government grants for maintenance, resulting in an overall monetary net benefit of at least 10 500 CNY ha⁻¹ (ca. 1600 USD ha⁻¹) on the long-term average. For a more complete understanding of Kökyar Protection Forest, future research should be directed towards quantifying the effect of its regulating ecosystem services, and on investigating the negative downstream consequences of its water consumption."

Comment 06:

"9 – 11: The abstract contains the apodictic statement: "The regulating ecosystem 10 services provided by Kökyar Protection Forest clearly reduce dust and sand storm impacts on Aksu City". But neither here nor in the actual article do the authors present any empirical evidence. Thus it remains an open question, whether the claimed ecological services of the shelterbelt system are really provided."

Response:

Comment partially adopted. The focus of our paper is on the institutional frameworks and economic conditions of Kökyar Protection Forest, and not on quantifying its ecosystem services. Nevertheless we must contradict this comment. We cannot find that this statement is apodictic. It is a hypothesis that can be verified and falsified by evidences. Since we have two evidences in favour of the statement (cf. chapter "4.2 The perspective of Aksu citizens") and none against it, for the time being we assume it to be true.

In response to this comment and in response to further comments by our referee Johannes Küchler (compare below), we rephrased the section containing the evidences in chapter "4.2 The perspective of Aksu citizens" in order to make the state of knowledge and the basis of the information more explicit. Furthermore we reinforced the argument of Kökyar providing regulating ecosystem services by a more detailed description of the nearby dust field that has been closed by the Kökyar Protection Forest, including its soil composition, position in reference to Aksu City, and main wind direction in the chapters "1.2 Geographic conditions of Aksu City" and "3.2 Site conditions".

Finally, since the queried statement appears to be provocative, and since in the abstract we do not want to put emphasis on a point that actually is not in the focus of the thesis, the statement has been replaced by a less controversial formulation.

Changes in the manuscript:

Citation from chapter “4.2 The perspective of Aksu citizens”: “An improvement of the dust and sand storm situation of Aksu City after the establishment of Kökyar Protection Forest is claimed by the Kökyar Annals (Kökyar Annals Compilation Committee, 1996; for details cf. next paragraph) and has been perceived and described by Kökyar farmers (socio-economic household survey 2012) and Aksu citizens (Aksu citizens interviews 2011; also cf. Halik, 2003).” For citations from chapter “1.2 Geographic conditions of Aksu City” and “3.2 Site conditions” (regarding dust field and main wind direction) cf. to comment 02.

Citation from “Abstract”: “In 1986, local authorities decided to establish a peri-urban shelterbelt plantation, the so-called Kökyar Protection Forest, with the aim to reduce dust and sand storm impacts on Aksu City by the regulating ecosystem services provided by the plantation.”

Comment 07:

23 The population figure of 570.000 refers to the total area of Aksu shi with more than 14.000 km². What is the population of Aksu’s actual urban core area to be protected by the Kökyar project?

Response:

Comment adopted. Answer: 314,500. The number has been integrated into the text.

Changes in the manuscript:

Citation from chapter “1.2 Geographic conditions of Aksu City”: “Aksu is a city of about 580 000 inhabitants of which 314 500 live in the urban core (Akesu Shi Renmin Zhengfu, 2012).”

Comment 08:

“1676 21 – 24 The introduction does not establish any link to the national Sanbei Fanghulin scheme.”

Response:

Comment adopted. A link has been established in chapter “1.1 Shelterbelts in China”.

Changes in the manuscript:

For citation from chapter “1.1 Shelterbelts in China” cf. to comment 01.

Comment 09:

“1-3: The topographic information is too general. The local topography of the urban area is of greatest relevance for the degree of impact of the annual dust and sand storms (see first lines of 1679)”

Response:

Comment adopted. The topography of the urban area and the afforestation site has been described in more detail in chapters “1.2 The geographic conditions of Aksu City” and “3.2 Site conditions”.

Changes in the manuscript:

For citations from chapter “1.2 Geographic conditions of Aksu City” and “3.2 Site conditions” cf. to comment 02.

Comment 10:

10: What is the official definition of a “sand storm event”? in 1685, 26, you speak of wind-born sand events. 20: Here you speak of dust storms. Is there any difference between a dust storm and a sand storm?

Response:

Comment adopted. The expression “sand storm event” is an alternative translation for “wind-born sand event” (fengshaci). It had remained in the text by accident. The whole section containing this expression has been rephrased and based on other data. The expression “wind-borne sand event” (fengshaci) is used throughout the Kökyar Annals. It seems to be an outdated expression in the scientific context, similar to the English word “sand storm”. Yet, since there is no data in modern scientific language, e.g. in TSP (total suspended particles) from before 1996, we have to operate with this expression. The reader is informed about the complications of the expression in the corresponding chapter (“4.2 The perspective of Aksu citizens”). “Dust and sand storms” (shachenbao) is a collective term for dust storms and sand storms. Dust storms and sand storms are principally distinguished by particle sizes, but in the Chinese terminology, usually the collective term is used. We have no information on the particle sizes of the storms in Aksu City, but since the northern surroundings contain both clay and sand, a combination of dust and sand is the most probable.

Changes in the manuscript:

Citation from chapter “1.2 Geographic conditions of Aksu City”: “[...] the arid environment becomes very tangible whenever the regular hot and dry north winds blow down from the Tian Shan Mountains (Föhn effect). Maximum wind speeds are reached in springtime with 15 m s^{-1} (Yoshino, 1992). Raising dust and sand from the barren areas north of the oasis, the north winds cause an annual average of 11.5 sand storm days (visibility less than 1 km) in Aksu City (Kökyar Annals Compilation Committee, 1996; also cf. chapter 3.2 Site conditions).

Comment 11:

“1677 12: “Hindukush–Himalaya–Tianshan region” What kind of region should this be? Dust and Sand Storms are primarily a meteorological event of the plains, not of high mountain areas.”

Response:

Comment adopted: This formulation was based on an international workshop held 2013 in Hamburg (“Climate Change and Environmental Pressure: Adaptation and Resilience of Local Communities in the Hindu-Kush-Himalaya (HKH)”), where the combination of mountains and plains in Hindukush, Himalaya and Tian Shan were seen as challenged by similar problems. Since we see that it looks strange without this context, it has been deleted.

Changes in the manuscript:

Citation from chapter “1.3 The Kökyar Protection Forest”: “It is a showcase project in China and could be a model for other drylands. [...] This analysis can turn out to be helpful for the planning or running of other similar projects, especially in geographically similar areas.”

Comment 12:

“13: “systematically examine the establishment process”: This bold claim raises high expectations. Again, as in the abstract: the introduction does not arrive at a research question.”

Response:

Comment adopted. The formulation has been replaced by an explicit research question.

Changes in the manuscript:

Citation from chapter "1.3 The Kökyar Protection Forest" (research question). "This paper undertakes an exemplary analysis of the Kökyar Protection Forest under the following research question: Under which institutional frameworks and to which financial conditions can peri-urban shelterbelts be established and maintained?"

Comment 13:

"18: data are drawn"

Response:

Comment not adopted. To our best knowledge and to that of our native proofreader (New Zealand), "is" is fine here.

Changes in the manuscript:

None.

Comment 14:

"19: survey on Kökyar farmers? Should it not be of ??"

Response:

Comment not adopted. To our best knowledge and to that of our native proofreader (New Zealand), "on" is fine here.

Changes in the manuscript:

None.

Comment 15:

"18-20: Since the objective of the study is not well identified, the information on methodology is "hanging in the air". Why interview farmers, why not meteorologists, medical doctors, old cadres?"

Response:

Comment adopted. The objective of the study has been clarified by the formulation of an explicit research question. In consequence, the information on methodology is not longer "hanging in the air".

Changes in the manuscript:

For citation from chapter "1.3 The Kökyar Protection Forest (research question) cf. to comment 12.

Comment 16:

"21: What's the meaning of "sound literature"?"

Response:

Comment adopted. The word “sound” has been deleted.

Changes in the manuscript:

Citation from chapter “2. Methods”: “Literature on Kökyar is scarce and until today available exclusively in Chinese.”

Comment 17:

“1678 23: There is a national context for the Kökyar project: the 3 North shelterbelt system”

Response:

Comment adopted. The national context has been incorporated into chapter “1. Introduction” as subchapter “1.1 Shelterbelts in China”.

Changes in the manuscript:

For citation of chapter “1.1 Shelterbelts in China” cf. to comment 01.

Comment 18:

“1679 3: “Saline desert plateau” Such words suggest potential problems of salinization. Did they occur? They also suggest especially large quantities of irrigation water in order to “wash” the land to make it suitable for tree planting. But there is no mentioning of drainage facilities and drainage costs.

Response:

Comment adopted. Drainage canals have been added in the list of infrastructure items (chapter “3.3 Desing”) and in the list of tasks of the River Management Department (chapter “3.4 Key actors”). Furthermore, the salination problem has been explained in more detail in chapter “3.2 Site conditions”.

The drainage canals were simple earth ditches of a total length of 14.5 km which drained the southern parts of Kökyar I by the natural slope of the area. Being a small and rather cheap detail of the overall infrastructure, its costs are subsumed in Table 2 under the costs of water engineering. Explaining these (and other) technical details in the text would overload the paper.

Changes in the manuscript:

Citation from chapter “3.3 Design”: “Furthermore, the area is equipped with all necessary technical infrastructure, such as water gates, waterlocks, overflows, bridges, drainage canals, water tabs, power lines, telephone lines and administrative buildings.”

Citation from chapter “3.4 Key actors”: “The main task of the River Management Department and its local Water Management Station lay in preparing the planting ground through spatial planning, bulldozing the terrain, establishing a road network, building irrigation canals and other hydraulic engineering for provision of irrigation water, and drainage canals to depress the saline ground water level (Kökyar Annals Compilation Committee, 1996; interview 1) [...]”

For citation from chapter “3.2 Site conditions” cf. to comment 02.

Comment 19:

“2-6 The question of site selection remains nebulous: Please include a graph showing major wind directions and velocities (should be combined with fig 2) and give some information on the nature and quantity . of “sand” and suspended dust. How reliable were the meteorological data? What about soils as a source for wind erosion and being exposed to salinization?”

Response:

Comment adopted. The question of site selection has been clarified by insertion of chapter “1.2 The geographic conditions of Aksu City” and chapter “3.2 Site conditions”. Main wind direction and velocities have been added to the text in chapter “1.2 The geographic conditions of Aksu City”. The main wind direction has also been incorporated into Figure 2. We do not have information on nature and quantity of suspended dust and sand of the past, but since the northern surroundings contain both clay and sand (cf. chapter “3.2 Site conditions”), a combination of dust and sand is the most probable. We have no specific information about the reliability of the meteorological data. Of course, soils are a source for wind erosion, and they are exposed to salination.

Changes in the manuscript:

For citations from chapter “1.2 The geographic conditions of Aksu City” and chapter “3.2 Site conditions” cf. to comment 02. The changed Figure 2 will be uploaded separately.

Comment 20:

“2: the relevance of local topography for the potential impact of the project is hidden behind the information, that the project was established on “a 20 m high saline desert plateau”. If I am not mistaken “high” here means 20 m high above the level of the Aksu River flood plain.”

Response:

Comment adopted. The relevance of the local topography and its influence for the impact of the project have been further clarified by adding the chapters “1.2 Geographic conditions of Aksu City” and “3.2 Site conditions”.

Changes in the manuscript:

For citations from chapter “1.2 The geographic conditions of Aksu City” and chapter “3.2 Site conditions” cf. to comment 02.

Comment 21:

“4: the plots of 0,5 – 1 ha exclude or include poplar plantations??”

Response:

Comment adopted. They may include poplar shelterbelts in single or double rows at the edges of the plots, but they do not include the 100 m wide shelterbelts at the main axis of the area.

Changes in the manuscript:

Citation from chapter “4.1 The leasing system”: “Leasing contracts guarantee them, for a period of about 10 to 15 years, a small section of orchard land (mostly between 0.5 and 1 ha, which may include single or double row poplar shelterbelts on one or two edges of the plots), regular irrigation water supply and some technical advice in fruit production (socio-economic household survey 2012).”

Comment 22:

“11-12: the terms “ecological forest” and “economic forest” were introduced with the PRC forestry law (1984) please explain in foot note as many readers may not be familiar with this context.”

Response:

Comment not adopted. The terms “ecological forest” and “economic forest” are easily misinterpreted, do not fit the categories of Kökyar Protection Forest well, and are not vital for the paper. Instead of explaining them in footnotes, we therefore preferred to omit them.

Changes in the manuscript:

Citation from chapter “3.3 Design”: “The plantation was established as a raster of shelterbelt strips consisting mainly of white poplar (*Populus alba* ‘Pyramidalis’) with fruit plantations between. In the five years between 1986 and 1990, 686 ha of poplar shelterbelts and 623 ha of orchards were planted, totalling 1308 ha and 1 085 000 trees (Kökyar Annals Compilation Committee, 1996).

Comment 23:

“25 Am I interpreting you correctly?: The new land-use-system is indeed a pure forestry system, (not agro-forestry, not silvo-pastoral) excluding cover crops (grain, fodder plants) and cattle breeding (sheep)???? Was water shortage the reason for omitting animals?”

Response:

Comment adopted. The land-use system is not a pure forestry system, as is explained in chapter “4.3 The perspective of the farmers”. To avoid further misunderstandings, we inserted a link to this chapter in the queried section.

Changes in the manuscript:

Citation from chapter “3.3 Design”: “The rectangular fields in between are filled with orchards (for details of the orchard management cf. chapter 4.3 The perspective of the farmers).”

Comment 24:

“1680 25: You speak of irrigation canals but what about drainage canals?”

Response:

Comment adopted. For explanation cf. to the response to comment 18:

Changes in the manuscript:

For citations from chapters “3.3 Design”, “3.4 Key actors”, and “3.2 Site conditions” cf. to comment 18.

Comment 25:

“1681 23: compulsory afforestation. What is the Chinese term (foot note)? Relation to yiwugong?”

Response:

Comment adopted. For explanation cf. to the response to comment 04.

Changes in the manuscript:

For the citation including the Chinese term also cf. to comment 04.

Comment 26:

“1682 4: suggests the participation of “workers”: Did farmers not participate?”

Response:

Comment adopted. The word “workers” has been exchanged for “manpower” and “workmen” to avoid misunderstandings. Farmers did not participate, as made clear in the same paragraph.

Changes in the manuscript:

Citation from chapter “3.5 Compulsory labour”: “Even so, the mobilisation of manpower reached very high levels: About 70 different organisations and enterprises sent thousands of workmen twice a year, for periods of 8, 12 or even 30 days at a time (cf. Fig. 4).”

Comment 27:

“19: “drinking water facilities” Where did/does drinking water for the isolated farm houses come from? How was/is it produced and distributed?”

Response:

Comment not adopted. Electric wells provide drinking water from deep ground water layers. However, we do not want to burden the paper with additional technical details.

Changes in the manuscript:

None.

Comment 28:

“1683 25: In 1987 the leasing of reforested land to individual farmers began in many parts of China. It was apparently part of a national policy.”

Response:

Comment adopted. The national policy context has been added to chapter “4.1 The leasing system”.

Changes in the manuscript:

Citation from chapter “4.1 The leasing system”: “In 1981, the State Council of the PR China had started promoting private forestry on a leasing basis by its “Resolution on Issues Concerning Forest Protection and Development” (*guanyu baohu senlin, fazhan linye ruogan wenti de jue ding*; for backgrounds cf. Delang and Yuan, 2015). In 1987, when the Kökyar afforestation work was still in the early stages, the Forest Management Station and Water Management Station reacted to this resolution and to the dire financial situation of their afforestation project, with the introduction of a leasing system that is fundamentally still in force today [...].”

Comment 29:

“1685 1: how huge is huge? Can you give some approximate figures?”

Response:

Comment adopted. Table 3, which presents exemplary area sizes of private main tenants, has been linked to the corresponding section. The word “huge” has been exchanged by the less emotional “large”.

Changes in the manuscript:

Citation from chapter “4.1 The leasing system”: “They act as main tenants who first make the necessary infrastructure investments and then sublease their large estates in small patches to hundreds of leasing households, compensating their initial investment costs with income from the subleases (for exemplary area sizes of main tenants comp. Table 3).”

Comment 30:

“11: What means “extreme temperature alleviation”? 13: “wind speed reduction”? Where is the evidence? Experiments in Central Europe suggest reductions in the immediate vicinity of tree rows, but not at more distant places. Theoretically there is “air humidification” because of the evaporating irrigation water. But does it have an impact on the downtown climate? “air filtration”: The proportion of large particles (“sand”) will probably be reduced due to their deposition within and behind the shelterbelt. But there will be almost no impact on the quantity of suspended particles/airborn particulate matter. “soil fixation”: This is an important question: Did the advocates of the project consider the shelterbelt site itself as a major source of wind erosion? Or did they assume that the neighbouring lands are the source of wind erosion? In case of the last supposition did the project initiators also consider a restoration of the natural shrub vegetation in the erosion area?”

Response:

Comment adopted. The section on extreme temperature alleviation (capping of heat and cold peaks), wind speed reduction, and air humidification had been marked as an assumption. In response to the comment, we made the assumption character of this section more explicit (chapter “4.2 The perspective of Aksu citizens”). The actual effect of these ecosystem services on the climate of Aksu City has not been researched by this paper, however, since the fringes of the afforestation area touch the fringes of Aksu City, an effect in at least the neighbouring quarters is probable. We agree with the comment on air filtration. The shelterbelt site itself was indeed considered as a source of wind erosion. In response to this comment, we made this fact more explicit in chapter “3.2 Site conditions”. Also the neighbouring areas further in the north must be seen as a source of wind erosion. There exists a programme for reducing livestock densities in the surroundings which aims at protecting the sparse natural vegetation, which, in response to this comment, has been added to chapter “4.2 The perspective of Aksu citizens.” We do not have any information on active restoration of the natural vegetation.

Changes in the manuscript:

Citation from chapter “4.2 The perspective of Aksu citizens”: “Shelterbelts in drylands are generally assumed to provide vital regulating ecosystem services, such as air humidification and cooling, wind speed reduction, air filtration and soil fixation (Yimit et al., 2006; Halik, 2003; Chokkalingam et al., 2006).”

Citation from chapter “3.2 Site conditions”: “The fluvial terrace itself is composed of brown desert soil lying upon a gravel bed. The grain size at the surface changes from sandy gravel in the north to sandy silt and clay in the south. A high groundwater table and the regional extreme evaporation rate result in an average soil salinity of 2.87% and pH-values of 7.1 to 9.0. Before the afforestation, the soil was predominantly devoid of vegetation, with some areas being sparsely covered by *Alhagi spec.* and other herbaceous plants. The barren soil of the Kökyar plateau was regarded as a major source of wind erosion, thus contributing to the regular northerly dust and sand storms in Aksu City (cf. Fig. 2; Kökyar Annals Compilation Committee, 1996; Aksu Prefectural Forestry Department and Kuqa Television Station, 2006).”

Citation from chapter “4.2 The perspective of Aksu citizens”: “[...] the precise contribution of Kökyar to this positive development is hard to determine, since there are more contributing factors in addition to Kökyar, such as the extension of the irrigated agricultural area around Aksu, the protection of the natural vegetation in the surrounding deserts and semi-deserts by a programme which reduces livestock densities, and fluctuations in precipitation patterns (interview 2; Yimit et al., 2006; Yang and Cui, 2006).”

Comment 31:

“15, 16: You speak of a “notable improvement of the dust and sandstorm situation”. This is a sweeping yet vague wording. It would be helpful and more convincing for the reader if you could briefly name some of the evidences provided by your sources.”

Response:

Comment adopted. We rephrased the queried section in order to make the content of our sources more explicit and to avoid vague wording. Furthermore, to prevent questions and misunderstandings, we linked the following paragraph, which presents all the details of one of the sources, to the queried section.

Changes in the manuscript:

Citation from chapter “4.2 The perspective of Aksu citizens”. “An improvement of the dust and sand storm situation of Aksu City after the establishment of Kökyar Protection Forest is claimed by the Kökyar Annals (Kökyar Annals Compilation Committee, 1996; for details cf. next paragraph) and has been perceived and described by Kökyar farmers (socio-economic household survey 2012) and Aksu citizens (Aksu citizens interviews 2011; also cf. Halik, 2003).”

Comment 32:

“28 how close is the “immediate vicinity”?”

Response:

Comment not adopted. Immediate means, the forest begins where the city ends, as displayed in Figure 2.

Changes in the manuscript:

None.

Comment 33:

26 “wind born sand events” Could you provide a precise definition? Until now the reader has the impression, that the authors feel quite fine with the data provided by their sources. It is only now – rather late – that one learns more about the ambiguity of the sources, the terms and data.

Response:

Comment adopted. For the term “wind-borne sand event” cf. to the response to comment 10. In response to this comment and to comment 10, we erased the expression “wind-borne sand event” from the text, except for chapter “4.2 The perspective of Aksu citizens”, where its ambiguity is discussed. Additionally, at its first appearance in this chapter, we have set it in quotation marks. Furthermore, we added a general comment on potential biases of the Kökyar Annals in chapter “2. Methods”.

Changes in the manuscript:

For changes in chapter “1.2 The geographic conditions of Aksu City” cf. to comment 10.

Citation from chapter “4.2 The perspective of Aksu citizens”: “The first volume of the Kökyar Annals illustrates the Kökyar effect by presenting figures for reduced “wind-borne sand events” (*fengshaci*) in three periods between 1954 and 1990 (cf. Table 4; Kökyar Annals Compilation Committee, 1996).”

Citation from chapter “2. Methods”: “Since all these sources were written or produced under the aegis of persons and organisations involved in the establishment process of the Kökyar Protection Forest, there is a certain danger of biases in favour of the project.”

Comment 34:

“1686 26 – 27: Earlier I asked for more detailed information about the local topography and site conditions: It is only now, that you inform the reader, that the project is located on “the largest dust fields in the region”. But then, it would be helpful to learn more about the characteristics of a “dust field” and the local dust fields in particular (proportion of clay/silt particles mixed with or without sand???)”

Response:

Comment adopted. In response to this comment and comment 02, the section of the introduction, describing the geographic conditions of Aksu City, has been enlarged and upgraded to a separate subchapter (chapter “1.2 The geographic conditions of Aksu City”). Furthermore, chapter “3. The establishment of Kökyar Protection Forest” has been enlarged by a subchapter which describes the topographic, pedologic and hydrologic details of the Kökyar afforestation site (chapter “3.1 Site conditions”).

Changes in the manuscript:

For citations of chapter “1.2 The geographic conditions of Aksu City” and chapter “3.1 Site conditions” cf. to comment 02.

Comment 35:

“Table 2: Which year do you take as the base year for the inflation adjustment?”

Response:

Comment adopted. As already had been described in chapter “2. Methods”, the base year is 2014. For the convenience of the reader, the year has now additionally been added to all concerning tables.

Changes in the manuscript:

The base year 2014 has been added in brackets to Table 2, 3, 5, 6, 7, and 8.
Exemplary citation from table 2: “Adjusted for inflation (2014) [million CNY]”

Comment 36:

“Table 4: The figures must be explained.”

Response:

Comment not adopted. The figures are already explained in detail in chapter “4.2 The perspective of Aksu citizens”. The combination of text and tables will become easier to read once the tables are inserted into the text at the right places.

Changes in the manuscript:

None.

Comment 37:

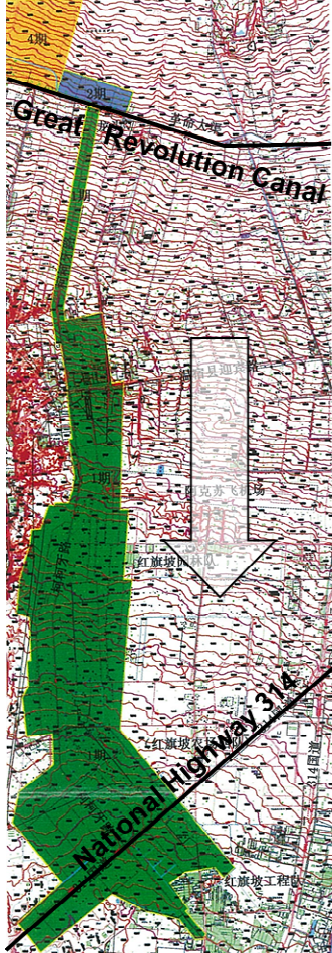
“Figure 2 should be reproduced turned by 90 degrees (vertical arrow pointing towards North) and enlarged to better read the informations provided (contour lines). This map should be combined with a wind diagram.

Response:

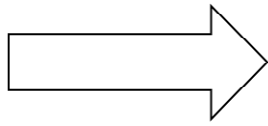
Comment adopted. The figure has been turned, enlarged, and combined with a wind diagram.

Changes in the manuscript:

The changed Figure 2 will be presented at the very end of this reply. It cannot be displayed in a bigger size in this online format.



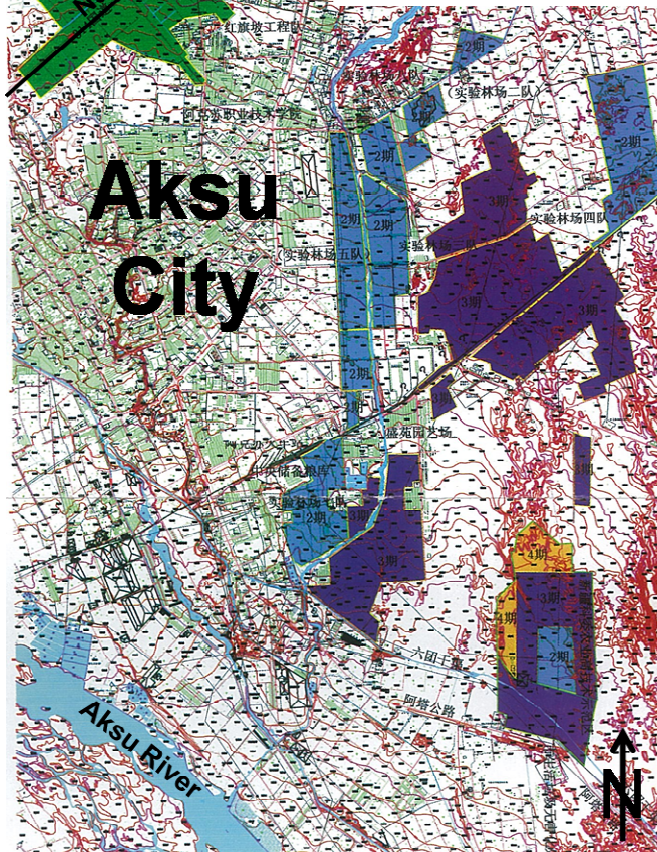
- Kökyar I
- Kökyar II
- Kökyar III
- Kökyar IV



main wind direction



5 km



|

**Establishment and maintenance of regulating ecosystem services in a dryland area of
Central Asia: The Kökyar Protection Forest, Aksu, NW China, as an example**

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Formatiert: Abschnittsbeginn:
Fortlaufend

15 Abstract

The city of Aksu, situated at the northern fringe of the Taklimakan Desert in ~~the northwest of~~ China, is exposed to periodic severe dust and sand storms. In 1986, local authorities decided to establish a peri-urban shelterbelt plantation, the so-called Kökyar Protection Forest, with the aim to reduce dust and sand storm impacts on Aksu City by the regulating ecosystem services provided by the plantation.~~Forest.~~ It was realised as a patchwork of poplar shelterbelts and orchards. The total area of the plantation reached 3800 ha in 2005. The Kökyar Protection Forest is exemplarily analysed to answer the following question: Under which institutional frameworks and to which financial conditions can peri-urban shelterbelts be established and maintained?~~The endeavour of planting the shelterbelt~~3,800 ha in 2005. This endeavour was made possible by the annual mass mobilisation of Aksu citizens, based on the Chinese regulation of the “National Compulsory Afforestation Campaigns”. Establishment costs amounted to ca. 60,000 CNY/RMB ha⁻¹ (ca. 10,000 USD ha⁻¹).~~The regulating ecosystem services provided by Kökyar Protection Forest clearly reduce dust and sand storm impacts on Aksu City.~~ Permanent maintenance of the plantation is facilitated by leasing orchard plots to private fruit farmers. ~~This system ensures forest tending, reduces government expenses, and provides incomes to farmers.~~ From the perspective of the local economy, annual farming net benefits generated by Kökyar fruit farmers more than compensate annual government grants for maintenance, resulting in an overall monetary net benefit of at least 10,500 CNY/RMB ha⁻¹ (ca. 1600~~1,600~~ USD ha⁻¹) on the long-term average.~~The intended regulating ecosystem services can thus be provided to the citizens of Aksu without payments for ecosystem services or other financial burdens.~~ For a more complete understanding of Kökyar Protection Forest, future research should be directed towards quantifying the effect of its regulating ecosystem services, and on investigating the negative downstream consequences of its water consumption.

40

1. Introduction

1.1 Shelterbelts in China

45 More than 40% of China's total territory is characterised by arid and semi-arid climates. These drylands are predominantly located in the north and especially in the northwest of the country (Li et al., 2012). Shelterbelts have been seen as an effective instrument to fight negative influences from deserts and semi-deserts ever since the beginning of the People's Republic of China (Chokkalingam et al., 2006). The objectives of shelterbelts usually comprise environmental security (alleviating soil erosion, droughts, dust and sand storms, dry hot winds etc.) and economic development (increasing crop production, stockbreeding production, timber production and other forest products etc.). Structures and species compositions of the plantations alter according to site-specific conditions and purposes (Li et al., 2012, Chokkalingam et al., 2006). The biggest and globally best-known shelterbelt, the so-called Three-North Shelterbelt, is an overarching project that aims at increasing forest cover from 5% to 15% in an area of 4 069 000 km² that stretches over 13 province level administrative units all from the northwest to the

55 northeast. Its establishment began in 1987 and is expected to last until 2050. 244 690 km² have been afforested so far (Li et al., 2012).

A special shelterbelt type has developed in the Tarim Basin in northwest China. The Tarim Basin is framed by the Tian Shan Mountains in the north and the Kunlun and Karakorum Mountains in the south and southwest, the Taklamakan Desert lying in the middle. Continental position, precipitation shadow of the mountain ranges, and intense solar radiation form a hyper-arid climate. Oasis cities are located along the periphery of Taklamakan Desert, wherever rivers, running down from the surrounding mountains, provide sufficient water (cf. ~~Aksu is a city of about 570,000 inhabitants (Intercontinental Pan-Chinese Network Information Co.-Ltd., 2008)-Fig. 1~~). Most of these cities, such as Korla, Būgūr, Aksu, Kashgar or Hotan, have

65 experienced a rapid growth over the last decades, in the course of which natural greenbelts

formed by native tree and shrub species have been eliminated by urban sprawl and agriculture.
In order to protect the citizens from the influences of the surrounding desert lands, authorities of
all these cities try to establish a special type of shelterbelt which could be labeled as peri-urban
protection forest: broad greenbelts that optimally should surround the cities from all sides (Halik,
70 2003). The Kökyar Protection Forest in Aksu was one of the first of these.

1.2 Geographic conditions of Aksu City

Aksu is a city of about 580 000 inhabitants of which 314 500 live in the urban core (Akesu Shi
Renmin Zhengfu, 2012). It is the capital of Aksu Prefecture, lying in the west of China's
75 northwestern Xinjiang Uyghur Autonomous Region, close to the border of Kyrgyzstan. At a
geographical position of 41°10' north and 80°15' east and at an altitude of ~~1100~~^{1,400} m above
sea level, it is situated on a long, slightly inclined slope between the Tian Shan Mountains in the
north and the Taklimakan Desert in the south (cf. ~~Fig. Fig. 1).~~ The slope is traversed from
northwest to southeast by the Aksu River, which is fed by snow and glacier melt water as well as
rainfall from the nearby Tian Shan Mountains as introduced in Rumbaur et al. (submitted to this
80 issue). The Aksu River formed a flat 10 km wide river valley with a steep cut bank of about 20 m
height at its northeastern shore. The core of Aksu City lies exactly under the cut bank within the
river valley, while today's suburbs spread deeper into the valley and on the bank.

An annual evaporation rate of ~~1868~~¹. ~~An annual evaporation rate of 1,868~~ mm and annual
precipitation of merely 75 mm indicate an extremely arid climate (Kökyar Annals Compilation
85 Committee, 2006). ~~Due~~^{However, due} to its location at the Aksu River, Aksu receives sufficient
water to ensure agriculture, which places the city ~~in~~^{at the very centre of} a huge river oasis (ca.
~~1000~~^{1,000} km², including Awat and Onsu County; Halik, 2003). ~~However, the arid environment~~
becomes very tangible whenever the regular hot and dry north winds blow down from the Tian
Shan Mountains (Föhn effect). Maximum wind speeds are reached in springtime with 15 m s⁻¹
90 (Yoshino, 1992). Raising dust and sand from the barren areas north of the oasis, the north winds
cause an annual average of 11.5 sand storm days (visibility less than 1 km) in Aksu City (Kökyar

[Annals Compilation Committee, 1996; also cf. chapter 3.2 Site conditions](#)). [The severe dust and sand storms of Aksu are blackening](#) ~~The water of the Aksu River stems from snow and glacier melt water as well as rainfall from the nearby Tian Shan Mountains as introduced in Rumbaer et al. (submitted to this issue).~~

~~In the years between 1954 and 1986, the city annually experienced an average of 11 to 12 "sand storm events" (Kökyar Annals Compilation Committee, 1996). The storms were severe, darkening~~ the sky, making respiration difficult, covering everything outside and inside houses with brown dust, inhibiting traffic, and disrupting public life (Aksu Prefectural Forestry

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Department [and](#) Kuqa Television Station, 2006; Aksu Prefectural Greening Committee, 2006; Aksu citizen interviews 2011).

[During](#) ~~in~~ the [1980s, the dust and sand storms were increasingly perceived as a major problem to the city. There are two probable factors for this change: Firstly, in the previous decades, Aksu City had undergone](#) ~~same period,~~ fast socio-economic changes; ~~took place in the city:~~ The composition of the population shifted from a nearly [100%pure](#) autochthonous Uyghur society to a majority of foreign Han-Chinese settlers, and the city was transforming from a small rural oasis town into a regional industrial and service centre (Halik, 2003; Intercontinental Pan-Chinese

Network Information Co. Ltd., 2008). [A different environmental and cultural background of the settlers and shifted ideas of the living standards in cities may have fostered the new problem perception. Secondly, the immigration-based growth and the economic development of oasis cities in the Tarim Basin usually was accompanied by degradation of the natural vegetation at the fringes of the oases, thus compromising their regulating ecosystem services and contributing to a factual aggravation of dust and sand problems \(Halik, 2003\). However, there is no literature on the specific situation around Aksu City. As a result of these changes, dust and sand storms](#) ~~were increasingly perceived as a major problem to the city.~~

1.3 The Kökyar Protection Forest

As a response to the dust problems, in the 1980s the local authorities decided to lay out a peri-urban shelterbelt plantation, called Kökyar Protection Forest. Work began in 1986 and was completed in 1990, the plantation then covering an area of ~~13081,308~~ 13081,308 ha (Kökyar Annals Compilation Committee, 1996). From 1990 onward, the project was enlarged by three more project periods, each of which converted more patches of desert land into forest plantations (cf. Fig. 2). The four project periods and their corresponding areas were then chronologically labeled from Kökyar I to IV, while the complete title, Kökyar Protection Forest, usually refers to the sum of the four project areas. According to local authorities, the total area covered ~~38423,842~~ 38423,842 ha by 2005 (Kökyar Annals Compilation Committee, 2006; Aksu Prefectural Greening Committee, 2006).

The Kökyar Protection Forest is not unique, but rather forms part of a series of such greening projects in different cities of the Tarim Basin, e.g. in Korla, Kashgar, and Hotan (Halik, 2003). However, among them all, Kökyar is regarded as a kind of lighthouse project, due to its vast dimensions, and because it was realised without the aid of the central government. An accompanying propaganda effort, including the publication of books and documentaries as well as the erection of a large exhibition hall, further boosted its prominence. In 1996, it was included in the “Global 500 Role of Honour for Environmental Achievement” of the United Nations Environmental Programme (Kökyar Annals Compilation Committee, 1996). It is a showcase project in China and could be a model for ~~other drylands, the whole Hindukush-Himalaya-Tianshan region.~~ This ~~is reason enough for this~~ paper undertakes an exemplary analysis of the Kökyar Protection Forest under the following research question: Under which institutional frameworks to systematically examine its establishment process and to which financial conditions can peri-urban shelterbelts be established and maintained? analyse its present functioning. This analysis can turn out to be helpful for the planning or running of other similar projects, especially in geographically similar areas ~~of the Hindukush-Himalaya-Tianshan region.~~

2. Methods

The data for this paper is drawn from existing literature on the Kökyar Protection Forest, a socio-economic household survey on Kökyar farmers conducted by the authors in 2012, and some
145 additional interviews conducted by the authors in 2011 and 2012.

[Literature](#)~~Sound literature~~ on Kökyar is scarce and until today available exclusively in Chinese.

The main sources of information on the project are: firstly, the “Annals of the Kökyar Greening Project” in two volumes, provided by the Kökyar Annals Compilation Committee, a committee constituted by the project managers; secondly, a picture book called “Green Kökyar” produced
150 by the Aksu Prefectural Greening Committee; and thirdly: a documentary with the title of “The Green Feat: Commemorating 20 Years Construction of Kökyar” by the Aksu Prefectural Forestry Department and the Kuqa Television Station. This paper draws heavily on the “Kökyar Annals”, especially for the description of the establishment process of Kökyar, and, to a minor extent, on
155 the other two sources. [Since all these sources were written or produced under the aegis of persons and organisations involved in the establishment process of the Kökyar Protection Forest, there is a certain danger of biases in favour of the project.](#)

The existing sources of information on Kökyar neglect to give any figures for the running costs of the project or the actual economic situation of the farmers within its area. To close this knowledge gap, a socio-economic household survey was conducted in 2012. A raster of 19
160 evenly distributed sample points was projected on the whole area of Kökyar I, and subsequently the closest available household to each ideal sample point was identified. All the sample households lie within a radius of 200 m from the ideal sample points. The heads of the 19 identified households were interviewed in Chinese (except for one that was interviewed in Uyghur) according to a fixed questionnaire.

[For information on the institutional processes and economic conditions of the state-owned organisations running the project, a semi-structured interview with the former head of the Forest Management Station was conducted. Other important information on the general circumstances](#)

all around the Kökyar Protection Forest were gathered by interviews with random Aksu citizens, a private farming consultant in Aksu, and a seasonal worker in the plantation. All these interviews were conducted between ~~For some additional information, semi-structured interviews with former staff of the protection forest and other persons were conducted in~~ 2011 and 2012 (cf. Appendix A).

In order to make costs and incomes of Kökyar Protection Forest comparable between all different time periods between 1986 and today, monetary values will be presented adjusted for inflation, in their actual monetary value of the year 2014. The Chinese ~~yuan, currency, renminbi,~~ is abbreviated as ~~CNY, RMB, 1 RMB~~ is traded at about 0.16 USD.

The economic situation of the main actors of the Kökyar Protection Forest (i.e. private fruit farmers within the plantation and state-owned managing organisations) is estimated by cash based accounting. The effect of the Kökyar Protection Forest on the local welfare is summarised from the perspective of cost-benefit analysis. Cost-benefit analysis is an assessment method that “quantifies in monetary terms the value of all consequences of a policy to all members of society” (Boardman et al., 2011). In contrast to normal accounting practices applied by profit-oriented corporations to identify the most profitable investment opportunities, cost-benefit analysis is not limited to the monetary costs and benefits of the decision maker himself, but accounts for all marketable and non-marketable costs and benefits experienced by all individuals residing within the area of interest (Mishan and Quah, 2007). In a nutshell: a “benefit” is an increase in human wellbeing, and a “cost” is a reduction in human wellbeing (OECD, 2006). The term “net benefit” (i.e. subtraction of costs from benefits) therefore represents the overall societal welfare gain of a country or region. For the analysis conducted in this paper, the scope will be narrowed down to the local level, which means that downstream ecological costs caused by the Kökyar water consumption, although undoubtedly existent, will not be included. The focus will be set on marketable costs and benefits, while non-marketable effects will be verbally described (for more general information on cost-benefit analysis cf. ~~The effect of Kökyar~~

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195 ~~Protection Forest on the local economy is analysed using a cost-benefit approach, but without performing a full step-by-step cost-benefit analysis (for further details of this method cf. Boardman et al., 2011).~~

3. The establishment of Kökyar Protection Forest

3.1. Emergence

200 The first scheme of the later Kökyar Protection Forest came up in 1985, when water was needed for planned road side greening along National Highway 314 north of the urban core of Aksu. The Aksu Prefectural Party Committee decided to build a new fork canal from the existent northern Great Revolution Canal (*geming daqu*) leading southward to the planned greening site (cf. Fig. 2). The terrain to be crossed by the canal was the area of the later Kökyar Protection Forest. ~~a 20 m high saline desert plateau traversed by deep erosion gullies.~~ Because of ~~its~~ this unfavourable environment (cf. following chapter), it was decided to protect the canal with poplar shelterbelts on each side. A year later, in 1986, the original plan was enlarged to cover the whole area ~~barren plateau~~ with a protection forest, and the evocative title “Kökyar Greening Project” was suggested (Kökyar Annals Compilation Committee, 1996). “Kökyar” means “green cliff” in Uyghur language.

210 3.2 Site conditions ~~Design~~

215 The plantation site of the Kökyar Protection Forest lies in the north of Aksu City. It is a long stretch with an area of 1308 ha that extends 15.8 km from the Great Revolution Canal in the north to the suburbs of Aksu City in the south (cf. Fig. 2). It lies above Aksu City on an old fluvial terrace which slightly slopes from 1230 m above sea level in the north to 1125 m above sea level in the south. Most of its western boundary is defined by a steep cut bank of 20 m down to the Aksu River valley. The cut bank was canyoned by erosion gullies which extended deep into the area of later Kökyar, thus posing great problems for the levelling of the planting ground and construction of canals (Kökyar Annals Compilation Committee, 1996).

The fluvial terrace itself is composed of brown desert soil lying upon a gravel bed. The grain size at the surface changes from sandy gravel in the north to sandy silt and clay in the south. A high groundwater table and the regional extreme evaporation rate result in an average soil salinity of 2.87% and pH-values of 7.1 to 9.0. Before the afforestation, the soil was predominantly devoid of vegetation, with some areas being sparsely covered by *Alhagi spec.* and other herbaceous plants. The barren soil of the Kökyar plateau was regarded as a major source of wind erosion, thus contributing to the regular northerly dust and sand storms in Aksu City (cf. Fig. 2; Kökyar Annals Compilation Committee, 1996; Aksu Prefectural Forestry Department and Kuga Television Station, 2006).

3.3 Design

The plantation was established as a raster of shelterbelt strips consisting mainly of white poplar (*Populus alba* 'Pyramidalis'), i.e. the so-called "ecological forest", with fruit tree plantations between, i.e. the so-called "economic forest". In the five years between 1986 and 1990, 686 ha of poplar shelterbelts and 623 ha of orchards were planted, totalling 1,309 ha and 1,085,000 trees (Kökyar Annals Compilation Committee, 1996).

The infrastructure backbone of the plantation is formed by a vertical main canal and a parallel main asphalt road which interlink the Great Revolution Canal in the north with the city of Aksu in the south, providing the area with water and making it accessible. This main axis has a length of 15.8 km and is protected by a shelterbelt strip of 100 m width at each side. The areas east and west of it are criss-crossed by a regular grid of in total about 125 km earth roads and a hierarchical system of subordinate irrigation canals. Shelterbelts, planted in single or double rows, protect the earth roads and subordinate canals, forming a checkered pattern over the area (cf. Fig. 3). The rectangular fields in between are filled with orchards (for details of, with apple and pear being the orchard management cf. chapter 4.3 The perspective of the farmers), major crops and jujube, walnut and others being minor crops (Kökyar Annals Compilation Committee,

245 | ~~1996; socio-economic household survey 2012~~. Hundreds of small farm houses are scattered all
over the orchards. Furthermore, the area is equipped with all necessary technical infrastructure,
such as water gates, waterlocks, overflows, bridges, ~~drainage~~ sewer canals, water tabs, power
lines, telephone lines and administrative buildings.

Today, the shelterbelts of Kökyar I consist mainly of white poplar (*Populus alba* 'Pyramidalis') in
250 dense rows, partly mixed with Euphrates poplar (*Populus euphratica*), and some oleaster
(*Elaeagnus angustifolia*), tamarisks (*Tamarix*) and willows (*Salix*) in the understory. Most white
poplars have reached breast diameters of 20-30 cm, with some reaching up to 60 cm (field
observations 2012).

The later project periods of Kökyar II, III and IV are not located in the direct vicinity of Kökyar I.
255 They are scattered over the most problematic dust fields to the north and east of Aksu City (cf.
Fig. 2). Their lay-out follows the basic design of Kökyar I, but they tend to have smaller
shelterbelt areas compared to total area (cf. Table 1; Aksu Prefectural Greening Committee,
2006). For the latest scheduled project period, Kökyar IV, data have yet to be published.

3.43.3 Key actors

260 In 1986, the Prefectural Party Committee authorised two important governmental organisations,
the Aksu River Drainage Area Management Department ([akesu heliuyu guanlichu](#)) and the
Prefectural Forestry Department ([diqu linyechu](#)) to run the project jointly. Each of them founded
an on-the-ground working station especially for the purpose of establishing and managing the
plantation: the Kökyar Greening Project Water Management Station ([kekeya lühua gongcheng](#)
265 [shui guanzhan](#); (from here on referred to as Water Management Station) and the Kökyar
Greening Project Protection Forest Management Station ([kekeya lühua gongcheng fanghulin](#)
[guanzhan](#); (from here on referred to as Forest Management Station) with a staff of about 50
persons each (Kökyar Annals Compilation Committee, 1996; interview 1). The main task of the
River Management Department and its local Water Management Station lay in preparing the
270 planting ground through spatial planning, bulldozing the terrain, establishing a road network,

building irrigation canals and [other hydraulic engineering for provision of irrigation water, and drainage canals to depress the saline ground water level](#)~~providing water resources~~ (Kökyar Annals Compilation Committee, 1996; interview 1), while the main task of the Forestry Department and its local Forest Management Station lay in forest design planning, provision of cuttings and saplings and afforestation management (Kökyar Annals Compilation Committee, 1996).

Many other governmental organisations or government owned enterprises, e.g. the Prefectural Traffic Department, the Prefectural Road Construction Group, the state-owned Experimental Forest Site, or the equally state-owned Red Flag Slope Farm contributed to the establishment of Kökyar Protection Forest with expertise, labour, resources or money, however, the main promoters were the River Management Department and the Forestry Department with their corresponding on-the-ground stations (Kökyar Annals Compilation Committee, 1996; interview 1). Due to lack of funds, none of these institutions were given additional funds by the local government. Therefore, they had to restructure their regular annual budgets in order to mobilise funds for the project (Kökyar Annals Compilation Committee, 1996; interview 1).

Kökyar II (1991-1998) was organised and implemented by the same governmental institutions, and in the same manner, as Kökyar I.

For Kökyar III, in contrast, a market economy approach was chosen: The land was given to private entrepreneurs who were freed from rent payments and water fees for the first couple of years but had to make all other necessary investments themselves. In return, they can keep all revenues generated on the land for themselves, according to the principle “who invests earns” (Aksu Prefectural Greening Committee, 2006).

3.53-4 Compulsory labour

In order to meet the challenge of establishing huge forest areas in a poor financial situation, a legal regulation adopted in 1981 obliging all Chinese citizens to participate in “National Compulsory Afforestation Campaigns” ([quanmin yiwu zhishu yundong](#)) played a key role (Halik,

2003; interview 1). Based on this regulation, [beginning](#) from 1986 the Aksu Prefectural Party Committee called “all citizens, no matter which ethnicity, military or civilian” to participate in compulsory labour ([yiwu laodong](#)) on the fields, levelling the terrain, preparing the ground and planting trees with hard physical labour (Kökyar Annals Compilation Committee, 1996; interview 1). In reality, it seems that mainly prefectural governmental organisations and prefectural government owned enterprises under direct order of the Aksu Prefectural Party Committee were convinced or forced to take part, e.g. prefectural administration, police, and prefectural schools (interview 1). Even so, the mobilisation of [manpower reached very high levels:](#)~~workers was~~ ~~tremendous:~~ About 70 different organisations and enterprises sent thousands of workmen~~s~~ twice a year, for periods of 8, 12 or even 30 days at a time (cf. Fig. 4). On one top day in 1988, ~~84598,459~~ people were working on the desert plateau simultaneously (Kökyar Annals Compilation Committee, 1996). ~~Although~~~~Astonishingly,~~~~although~~ the areas of Kökyar III were ~~given to~~ [be developed and exploited by](#) private investors, the system of calling ordinary citizens to compulsory labour was maintained, thus massively supporting newly evolving large landholders with gratis manpower (Aksu Prefectural Greening Committee, 2006).

3.63.5 Initial investment costs

The establishment costs of Kökyar I are more or less systematically listed in the Kökyar Annals (Kökyar Annals Compilation Committee, 1996), comprising the costs of bulldozing and other heavy earthworks, all types of water engineering, the construction of asphalt and earth roads, telephone and power lines, and the costs of afforestation proper, as they were borne by the major contributing organisations (cf. Table 2; Kökyar Annals Compilation Committee, 1996). However, some matters of expense are omitted by the Annals: Firstly, the costs of surveying, planning, organising etc.; secondly, the costs of establishing drinking water facilities; and thirdly, the costs of compulsory labour. While we cannot, in retrospect, ascertain the costs of the first and second point, there is a way to approximate the costs of the third point, compulsory labour. The Kökyar Annals exactly list the physical extent of compulsory labour performed for the

establishment of Kökyar Protection forest but fail to treat it as a matter of cost, probably because it appeared as cost-free to the project makers. However, compulsory labour did, of course, involve costs, but the costs were passed along as opportunity costs to those institutions, organisations and enterprises which had to provide the workers, and to the workers themselves who had to pay for shovels and picks as well as for transportation (interview 1). The opportunity cost of one man-day can be calculated by the fee of 30 CNYRMB people had to pay in case they were unable to attend to compulsory labour (interview 1; value not adjusted for inflation. Multiplying the value of this fee by 346,000 performed man-days, and further adding tool and transportation costs, reveals that compulsory labour, in fact, was the largest single expense of Kökyar I (interview 1; Kökyar Annals Compilation Committee, 1996). Adjusted for inflation and calculated per area, the overall establishment costs of Kökyar I amount to 61,245 CNYRMB ha⁻¹ or, if compulsory labour is excluded from the calculation, 38,700 CNYRMB ha⁻¹ (cf. Table 2). The validity of this cost calculation for Kökyar I, as it is given in the Kökyar Annals, can be cross-checked by comparison to the costs given for Kökyar III in another publication: A 2006 publication of the title "Green Kökyar" indicates the establishment costs of Kökyar III based on the examples of one single investor commanding over 333 ha and a group of 13 investors commanding over 1200+200 ha (Aksu Prefectural Greening Committee, 2006). Adjusting their costs from inflation and calculating them per area allows a comparison between the establishment costs of Kökyar I and Kökyar III (cf. Table 3). The comparison shows that installation costs of both project periods are, roughly speaking, of the same magnitude. The coherence between those numbers can be taken as evidence that the cost calculation of Kökyar I is realistic, and that the costs of the past are transferrable to the present. ~~The fact that per-area costs of Kökyar III appear to be slightly lower than the costs of Kökyar I could be explained either by the superior work efficiency or inferior work quality of the private sector approach.~~

4. The present functioning of the Kökyar Protection Forest

4.1 The leasing system

350 [In 1981, the State Council of the PR China had started promoting private forestry on a leasing basis by its “Resolution on Issues Concerning Forest Protection and Development” \(*guanyu baohu senlin, fazhan linye ruogan wenti de jueding*; for backgrounds cf. Delang and Yuan, 2015\).](#)

[In 1987, when the Kökyar](#)~~Back in 1987, when~~ afforestation work was still in the early stages, the Forest Management Station and Water Management Station [reacted to this resolution and to the](#)
355 ~~out-of-the~~ dire financial situation [of their afforestation project,](#)~~came up~~ with [the introduction of](#) a leasing system that is fundamentally still in force today: Plots of already planted orchards, and plots which were ready for planting were [leased](#)~~offered~~ to private [fruit farmers](#)~~lesers~~ (Kökyar Annals Compilation Committee, 1996). Leasing contracts guarantee them, for a period of about 10 to 15 years, a small section of orchard land (mostly between 0.5 and 1 [ha, which may include](#)
360 [single or double row poplar shelterbelts on one or two edges of the plots](#)),~~ha~~, regular irrigation water supply and some technical advice in fruit production.~~On this basis, an apparently satisfactory farming income can be generated by the leasers~~ (socio-economic household survey 2012). The leasers, in return, have to pay a substantial lease and an irrigation water fee. Additionally, they have certain duties and prohibitions. The main duty is to annually attend 7 to
365 50 days of compulsory labour, which is mostly maintenance work on the shelterbelt plantations and the irrigation canals. The main prohibition is not to damage the poplar plantations by cutting of trees or branches (even if they overshadow fruit trees) or by grazing. The leasers have to compensate any loss of poplar trees on their area. Some contracts further contain prohibitions to change the cultivation from fruit trees to field crops, although it is anyhow economically the most
370 promising to cultivate fruit trees (socio-economic household survey 2012).

This system of economic incentives and regulative norms, as it is fixed in the lease contracts, guarantees the cultivation and persistence of vigorous orchards amongst undamaged poplar shelterbelts, it provides free labour for the maintenance of infrastructure and poplar shelterbelts,

and it ensures an income to the lessor organisations that they can reinvest into the plantation.

375 The project leaders soon recognised the leasing system as an instrument to successively transform Kökyar from a purely government-sponsored protection forest into a self-supporting protection forest (Aksu Prefectural Greening Committee, 2006). Consequently, they try to set the lease as high as possible, without the leasers backing out (interview 1; socio-economic household survey 2012).

380 Kökyar II is organised in parallel to Kökyar I.

Kökyar III also features an orchard leasing system, with the main difference being that the local government withdraws and private large-scale investors step into the role of the governmental lessor organisations: They act as main tenants who first make the necessary infrastructure

investments and then sublease their ~~large~~ huge estates in small patches to hundreds of leasing households, compensating their initial investment costs with income from the subleases (for exemplary area sizes of main tenants comp. Table 3). The exact conditions under which the main tenants obtain land from the government have not been researched ~~are presently unknown, as are the conditions under which they sublease it~~. However, it seems that privatisation of the protection forest business has advanced the idea of converting Kökyar into a self-supporting

390 system, as government grants have been reduced substantially ever since (Aksu Prefectural Forestry Department and Kuqa Television Station, 2006).

4.2 The perspective of Aksu citizens

Shelterbelts in drylands are generally ~~The Kökyar Protection Forest is~~ assumed to provide vital regulating ecosystem services, ~~for the nearby inhabitants of Aksu City,~~ such as air humidification and cooling, ~~extreme temperature alleviation,~~ wind speed reduction, air ~~humidification,~~ air filtration, and soil fixation (Yimit et al., 2006; Halik, 2003; Chokkalingam et al., 2006) ~~2003~~.

395 Among these, ~~wind speed reduction,~~ air filtration and soil fixation are of the greatest relevance for Aksu City, ~~most important items,~~ since these ~~this combination of~~ ecosystem services have ~~has~~ the effect of dust and sand storm mitigation, the primary reason for which Kökyar Protection

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400 Forest was initiated. [An improvement of the dust and sand storm situation of Aksu City after the establishment of Kökyar Protection Forest is claimed by the Kökyar Annals \(Kökyar Annals Compilation Committee, 1996; for details cf. next paragraph\) and has been perceived and described by Kökyar farmers \(socio-economic household survey 2012\) and Aksu citizens \(Aksu citizens interviews 2011; also cf. Halik, 2003\).](#) ~~It is well documented that there was a notable improvement in the dust and sand storm situation of Aksu City after the establishment of Kökyar Protection Forest (Kökyar Annals Compilation Committee, 1996; Kökyar Annals Compilation Committee, 2006; Halik, 2003; Aksu citizens interviews 2011; socio-economic household survey 2012).~~ However, the precise contribution of Kökyar to this positive development is hard to determine, since there are more contributing factors in addition to Kökyar, such as the extension

410 of the irrigated agricultural area around Aksu, the [protection of the natural vegetation](#) ~~reduction in livestock densities~~ in the surrounding [deserts and semi-deserts by a programme which reduces livestock densities.](#) and fluctuations in precipitation patterns (interview 2; Yimit et al., 2006; Yang ~~and~~ Cui, 2006).

415 -The first volume of the Kökyar Annals illustrates the Kökyar effect by presenting figures for reduced "wind-borne sand events" (*fengshaci*) ~~between the years~~ in three periods between 1954 and 1990 (cf. Table 4; Kökyar Annals Compilation Committee, 1996).

The figures demonstrate, first of all, that the situation in Aksu City and Onsu County Town, which are directly adjacent to Kökyar Protection Forest, improved considerably over this period, whilst at the Fifth Corps of the First Agricultural Brigade, which is 60 km away from Kökyar (Kökyar Annals Compilation Committee, 1996), wind-borne sand events remained frequent – thus indicating that *local* measures have caused this improvement. Furthermore, the table demonstrates that the situation at Aksu and Onsu was relatively stable between the first two periods, but suddenly grew massively better in the third period – thus indicating that a *new* measure starting from 1987 must have caused the improvement. Spatial and temporal

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425 coincidences combine to provide strong evidence for Kökyar being the main factor effecting the reduction of sand storm events.

This data set, however, does not clarify the physical properties of the alleged reduction, whereby the term “wind-borne sand events” obscures the duration of each “event” as well as the concentration of airborne particles. The second volume of the Kökyar Annals does present dust
430 quantities by annual averaged densities of “total suspended particles” (TSP), but only for the years from 1996 till 2006, thus not allowing a comparison with the previous years (Kökyar Annals Compilation Committee, 2006). For clarification of the exact dust and sand storm mitigation effect of Kökyar Protection Forest, more research is necessary.

Methods for the economic valuation of ecosystem services could theoretically attach annual
435 monetary values to dust and sand storm mitigation effects. The Kökyar Annals indeed present a precise figure for the Kökyar Protection Forest, attaching a value of 285 ~~CNY~~^{RMB} ha⁻¹ to the joint effect of airborne sand reduction and soil fixation (Kökyar Annals Compilation Committee, 1996; value adjusted for inflation). However, this figure is cited from a publication which is not focused on peri-urban protection forests in drylands, but rather aims at estimating an average
440 Chinese forest value (Qi, 2007; Lang ~~and~~ Li, 2000). Since Kökyar Protection Forest is established precisely on the largest dust fields in the region where it has the maximal impact on a large urban population in immediate vicinity, it is expected to have a far above-average value, and the presented figure is likely to understate the true monetary value of Kökyar’s regulating ecosystem services.

445 Because of uncertainties in respect to the physical properties as well as the monetary value of the dust and sand storm mitigation effect exerted by the Kökyar Protection Forest, this paper refrains from expressing the benefits of its regulating ecosystem services in monetary terms. Yet, the principal fact that Kökyar ~~significantly~~ reduces dust and sand storms appears to be beyond doubt.

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450 4.3 The perspective of the farmers

The following description of the socio-economic situation of the Kökyar farmers is based on a household survey conducted in 2012 on the area of Kökyar I. The transferability of the survey to Kökyar II and III is uncertain. Their leasing conditions may differ, while the market and environmental conditions are very similar.

455 The Kökyar I leasers recruit mostly from the huge pool of Han-Chinese migrant workers who jump at the chance to get settled there with their families (Kökyar Annals Compilation Committee, 1996; socio-economic household survey 2012). Families mostly have 2 to 5 members and both husband and wife are involved in farm work. During harvest time they may hire additional seasonal workers, while in winter some use their spare time to make extra money on Aksu City
460 construction sites. Their main agricultural income is generated by the cultivation of fruit trees and the resulting [harvests, with apple and pear being the major crops and jujube, walnut and others being minor crops. As long as fruit trees are still small and do not shade the soil surface, some leasers cultivate maize or cotton between the trees.](#)~~harvests.~~ In addition, many leasers can create indirect incomes from their land: Dead wood is used as fencing material or as fuel
465 substituting coal; small scale horticulture and husbandry beneath the fruit trees contribute to subsistence; animal dung provides some quantities of fertilizer. [However, only the fruit production is economically significant, and](#)~~However,~~ these indirect income items, although doubtlessly contributing to the living conditions of the farmers, are presently not quantifiable and cannot be incorporated into the subsequent income calculations.

470 The leasing contracts usually assign areas between 0.5 and 1 ha to the households, with some outliers at 2 ha or 3 ha, thus fostering small-scale farming. The lease is tailored to the age of the fruit trees and expected yield, shifting between 0 and 15,000 ~~CNY~~~~RMB~~ ha⁻¹. Irrigation water fees usually fall between [1125 CNY](#)~~1,125 RMB~~ ha⁻¹ and [1275 CNY](#)~~1,275 RMB~~ ha⁻¹. [\(These prices probably represent the costs of the irrigation infrastructure and operation; they do not reflect externalities.\)](#)
475 A high share of leasers additionally have to perform compulsory labour of

up to 50 man-days per year, its value being assessable by the fees they have to pay in case they are prevented. Besides the fixed costs for the lease, irrigation water and compulsory labour, the leasers need to make annual farming investments in fertilisers, pesticides, machinery, diesel, and harvest hands. While annual costs are rather steady, annual incomes vary from year to year, since the yields depend on weather conditions, pests, and natural fructification alternations (cf. Table 5). The net income shifts between 55,166 CNY/RMB ha⁻¹ in a year of good harvest (2010) and 11,465 CNY/RMB ha⁻¹ in a year of bad harvest (2011), with the long-term average being 47,376 CNY/RMB ha⁻¹.

Based on the household survey conducted in 2012, it can be estimated that the household members on average have to spend 180 man-days per leased hectare per year (socio-economic household survey 2012). Net farming incomes per working day can be calculated by dividing per-hectare net farming incomes by per-hectare work load (cf. Table 6).

While years of good harvests appear to provide satisfying incomes, years of bad harvest result in marginal incomes, with the income per man-day lying below the wage level of migrant workers and seasonal workers (socio-economic household survey 2012; interview 3). With such strong year-to-year variability, it is hard to evaluate their long-term income situation. However, from the perspective of the farmers themselves, the actual conditions seem to be promising on the long run, since during the household survey conducted in 2012 nearly all of them were optimistic for the future and declared themselves willing to sign up for the next leasing period (socio-economic household survey 2012).

4.4 The perspective of the governmental organisations

The state-owned~~The governmental organisations running the Kökyar Protection Forest (i.e. the Water Management Station and Forest Management Station as subsidiary bodies of the Aksu River Drainage Area Management Department and the Aksu Prefectural Forestry Department)~~ are the organisational backbone of the system. They are responsible for tending the shelterbelts, maintaining roads and canals, operating the irrigation system, managing and enforcing the

leasing system, and educating leasers in the cultivation of fruit trees. To fulfil these indispensable tasks, they are equipped with all necessary resources and staff, involving substantial costs (Kökyar Annals Compilation Committee, 1996; Kökyar Annals Compilation Committee, 2006; interview 1). A part of the costs can be covered by lease payments and irrigation water fees derived from the leasing households, yet from the perspective of the government budget, the system is far from economic self-sufficiency (interview 1). As it was not possible to conduct interviews with the persons responsible for the Kökyar project, no exact data on permanent government grants could be gathered. However, an interview with the former head of the Forest Management Station revealed that the Water Management Station and the Forest Management Station can only cover 30% of their expenses with the income generated from the lease and irrigation water fees. The remaining 70% of their budget is being covered by government grants (interview 1). Lease payments and irrigation water fees can be assessed at an amount of 5.765 million ~~CNY (8979 CNY RMB (8,979 RMB~~ ha⁻¹ lease and ~~1324 CNY 1,324 RMB~~ ha⁻¹ water fees, multiplied by 560 ha extant orchard area within Kökyar I. (socio-economic household survey 2012; Kökyar Annals Compilation Committee, 1996). This being their self-generated income share of 30%, the other 70% covered by governmental grants must amount to 13.451 million ~~CNY RMB,~~ and the total budget must add up to 19.215 million ~~CNY RMB.~~ Unfortunately, it is unknown how the budget is divided between the orchards and the shelterbelts.

In the very near future, the poplar shelterbelts will provide an additional income to the Water and Forest Management Station. Besides their protective value to the orchards, they also have a direct economic value in their timber, which needs to be harvested before becoming ~~over-mature~~. The earliest planted poplars are already almost fit for cutting. As soon as a systematic harvest begins, an annual wood increment of 21.5 m³ ha⁻¹ at a value of ~~8545 CNY 8,545 RMB~~ ha⁻¹ can be logged in the shelterbelt areas (Kökyar Annals Compilation Committee, 1996; monetary value adjusted for inflation). As investment costs for the shelterbelts

are unknown, there is no way to determine the net income they provide. However, a comparison between the expected gross timber income of ~~8545 CNY~~~~8,545 RMB~~ ha⁻¹ and both the gross and net income of the orchards (78,704 ~~CNY~~~~RMB~~ ha⁻¹, 47,376 ~~CNY~~~~RMB~~ ha⁻¹; see above) already shows that the shelterbelts are being by far less profitable than the orchards.

A timber income of ~~8545 CNY~~~~8,545 RMB~~ ha⁻¹ translates into an overall timber income of 4,785,144 ~~CNY~~~~RMB~~ for the area of Kökyar I (~~8545 CNY~~~~(8,545 RMB)~~ ha⁻¹, multiplied by 560 ha extant shelterbelts). This additional income reduces necessary annual government grants from 70% to 45% and, in absolute numbers, from 13.451 million ~~CNY~~~~RMB~~ to 8.666 million ~~CNY~~~~RMB~~ (values adjusted for inflation). Although a systematic harvest has not yet begun, timber is integrated into the income calculation, since it has regular annual increments which the governmental organisations could convert into income at any time. Incomes and costs of the two Stations are summarised in Table 7.

4.5 The perspective of the local economy

The Kökyar Protection Forest originated from the idea of protecting Aksu City against dust and sand storms. Yet, the invention of the orchard leasing system between the poplar shelterbelts gradually transformed it into a prospering branch of the local economy. The number of leasing households earning their livelihood in the orchards of Kökyar I can be estimated between 324 (Kökyar Annals Compilation Committee, 1996) and 454 (socio-economic household survey 2012). Extrapolated on the orchard area of Kökyar I, II, and III, these figures would allow an estimation of 1341 to 1880 farming households. In addition to these, a substantial number of jobs in the background organisation and in the poplar forests, and a smaller number of jobs for suppliers and commercial consumers can be assumed.

However, this whole branch is still dependent on annual government grants for the maintenance, regulation, and organisation tasks performed by the Water and Forest Management Station. This section sets out to clarify whether the government grants to Kökyar are justified solely by the protective ecosystem functions it provides, or whether it also benefits the local economy.

This question can be answered [from the perspective of cost-benefit analysis](#) by summing up all types of costs and ~~benefits, incomes,~~ as they were outlined in the previous sections, and calculating the net benefit. But prior to this, the figures of the previous sections need to be transformed to fit the needs of the net benefit calculation: Firstly, from the perspective of local economy it is necessary to account for the time farmers work in their orchards as an additional farming cost, since without the existence of Kökyar they would contribute to local economy through other activities. These opportunity costs are calculated at the same daily rate as the compulsory labour they have to perform for their lessors, that is 51.52 ~~CNY~~RMB day⁻¹ (socio-economic household survey 2012). Given that Kökyar farmers on average invest 180 working days per hectare of orchards (socio-economic household survey), the opportunity costs of farm work can be set at ~~9289 CNY~~9,289 RMB ha⁻¹ (value adjusted for inflation). Secondly, all costs and incomes of the farming households are in the previous sections given per hectare of orchard land, while costs of the Water and Forest Management Station are only known as a total number without differentiation into forest types and area sizes. In order to calculate in the same units, per-hectare numbers have to be transformed into total numbers. This is done by multiplying all farming incomes and expenses by 560 ha, the total extant orchard area within the borders of Kökyar I (Kökyar Annals Compilation Committee, 1996). After these preparations, all figures are ready for the net benefit calculation ([cf.](#) Table 8).

Subtraction of all costs from all benefits shows that Kökyar I in total generates an overall annual net benefit of 11.789 ~~million CNY~~ million RMB. Additionally, it provides regulating ecosystem services of a specific value which, however, could not be determined in terms of money. The local economy cycle of Kökyar I is graphically summarised in Figure 5.

The overall net benefit of 11.789 ~~million CNY~~ million RMB on the total forest area of Kökyar I expressed per area is 10,530 ~~CNY~~RMB ha⁻¹. This number, however, applies only to Kökyar I and should not be misunderstood as a general number transferable to Kökyar II, III, and IV. While Kökyar I has an orchard share of 50%, Kökyar II and III have greater orchard shares of 58% and 90%,

580 respectively. As mentioned previously, orchards are by far more profitable than shelterbelts, thus
Kökyar II and III can be assumed to create considerably greater net benefits to the local
economy than Kökyar I.

Thus, it can be concluded that government grants to the Kökyar Protection Forest do not only
provide a return in terms of regulating ecosystem services for the citizens of Aksu, but also in
585 terms of financial benefits. From the perspective of the local economy, the Kökyar Protection
Forest is self-supporting, with respect to annual farming net benefits more than compensating
necessary annual government grants. The regulating ecosystem services of wind speed
reduction, air filtration and soil fixation, with regard to which the Kökyar Protection Forest was
initiated, can therefore be provided to the citizens of Aksu without any payments for ecosystem
590 services (PES) or other additional financial burdens on the local economy.

Comparing the initial investment costs of 61 245 CNY ha⁻¹ with the overall annual net benefit of 10 530 CNY**5. Synthesis**

~~The Kökyar Protection Forest has been established in a harsh environment and with limited
financial resources. The Kökyar project was made possible by a multitude of governmental
595 organisations redirecting their regular resources from other pending projects to this one.
Furthermore, it required the mobilisation of a great number of Aksu citizens for compulsory
labour on the Kökyar fields over many years. The establishment of Kökyar I alone took 5 years
and involved costs of 61,245 RMB ha⁻¹. The establishment of Kökyar II and III took another 15
years and involved per area costs of roughly the same magnitude. The result is a peri urban
600 shelterbelt of 3,842 ha (as of 2005), which serves the intended purpose of protecting Aksu City
from dust and sand storms.~~

~~Due to the arid, saline environmental conditions, the Kökyar Protection Forest cannot persist
without permanent care in the form of replacement plantings, irrigation, and general
maintenance, which involves permanent costs. The governmental organisations running the~~

605 ~~Kökyar Protection Forest were able to generate own income by introducing an orchard leasing system, but they are still dependent on permanent grants from government coffers. Within the regulatory framework of the leasing contracts, orchard leasers act as independent businessmen and can generate substantial net incomes. From the perspective of the local economy, annual farming net benefits generated by the orchard leasers can more than compensate annual~~
610 ~~government grants, resulting in an overall annual net benefit of 10,530 RMB ha⁻¹ in the case of Kökyar I, and probably even more in the cases of Kökyar II and III.~~
~~Comparing the initial investment costs of 61,245 RMB ha⁻¹ with the overall annual net benefit of 10,530 RMB ha⁻¹ shows that net benefits at the current level would offset initial investment costs~~
within merely 6 years. However, this is not the actual payback period, since within the first 10 to
615 15 years after initialisation, fruit trees had not reached full fructification, and consequently there were no or only marginal annual net benefits. The actual historic development of the net benefit has not been researched, but under the simplified assumption of a linear net benefit
development from 0 ~~CNY~~RMB ha⁻¹ in the first project year to 10,530 ~~CNY~~RMB ha⁻¹ in the 25th
project year, the payback period can be roughly approximated at 20 years. In the case of Kökyar
620 II and III, the payback period can be assumed to be shorter, due to their higher orchard share.

5.6. Discussion and Outlook

The paper describes the historic establishment and present functioning of [the Kökyar Protection Forest](#) with regard to [its institutional frameworks and the operational processes as well as with regard to the financial conditions](#). [While the institutional frameworks of](#)
625 ~~Concerning the operational processes, the paper could describe~~ Kökyar I [and II are described](#) in satisfactory detail, [Kökyar III adopts a](#) ~~due to the available systematic documentation (especially the Kökyar Annals) and additional field research (Kökyar household survey, expert interviews).~~
~~Since Kökyar II is organised in the same way as Kökyar I, its operational processes are adequately covered by the description of Kökyar I. The differing~~ [more market based approach](#).
630 [which has not been systematically documented yet](#). ~~operational processes of Kökyar III,~~

~~however, could not be described at the same detail due to the lack of systematic documentation.~~

Further research could clarify the [institutional](#) functioning of ~~the new privatised approach chosen in~~ Kökyar III, especially in comparison to Kökyar I and II.

Concerning the description of the financial conditions, the ~~paper could reliably determine the establishment costs of Kökyar I based on sound sources, and there is good evidence that the figure are broadly transferable to Kökyar II and III. The~~ present financial conditions of ~~the~~ Kökyar

~~Protection Forest, by contrast,~~ have formerly not been subject to any publications, and the [results of the respective](#) ~~authors could base their~~ calculations [of this paper, being based only on a](#) ~~their own~~ socio-economic household survey [comprising and additional interviews. These](#)

~~calculations are based on a sample size of~~ 19 leasing households [and one additional expert interview with former leading staff of the state-owned organisations, are deemed to be rather rough estimates. Conducting](#) ~~within the area of Kökyar I. A bigger sample size, also comprising leasing households of Kökyar II and III, would have made the results more reliable. Furthermore,~~

~~it would have been desirable to conduct~~ interviews with [actual](#) leaders of the governmental organisations of Kökyar I and II, and with large private landholders of Kökyar III [would have been extremely desirable, however.](#) ~~However, this appears to be hard to achieve~~ under the present political tensions in Xinjiang and the resulting scepticism towards any type of social [surveys, this seems hard to achieve.](#) ~~surveys.~~

For a more comprehensive understanding of the costs and benefits of the Kökyar Protection Forest, future research should be directed towards two main fields. Firstly, the exact physical properties of the regulating ecosystem services provided by the Kökyar Protection Forest still need to be determined, especially regarding the amount of dust and sand avoided in the city of Aksu. Secondly, the negative consequences of the Kökyar water consumption for downstream ecosystems need to be investigated. Principally, every drop of water diverted from Aksu River for the purpose of irrigating the Kökyar Protection Forest is detracted from its lower reaches and its main stem, the Tarim River. [The improvement of the quality of life of Han-Chinese settlers in](#)

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|
| [Aksu is thus bought by the](#)~~The~~ resulting desiccation of downstream ecosystems and the
| consequent loss of downstream ecosystem services, [which deprives local Uyghur farmers and](#)
| [herdsmen of their livelihoods. Internalising these downstream effects into the Kökyar water](#)
660 | [prices](#) may challenge the [net-benefit and the](#) positive image of Kökyar Protection Forest.

|

Appendix A: List of interviews

Interview 1

665 Interviewee: Ibrahim Yusup, between 1986 and 1995 head of the Kökyar Greening Project
Protection Forest Management Station
Interviewers: Siegmund Missall, Abdulla Abliz, Aliya Badrulla
Place and date: Urumqi, 15 October 2012

670 Interview 2

Interviewee: Zhang Lei, private farming consultant in Aksu
Interviewer: Siegmund Missall
Place and date: Aksu, November 2011

675 Interview 3

Interviewee: name unknown, seasonal worker in the orchards of Kökyar Protection Forest
Interviewers: Siegmund Missall, Abdulla Abliz, Aliya Badrulla
Place and date: Aksu, January 2012

680 Aksu citizen interviews

Interviewees: random citizens on the streets of Aksu City
Interviewer: Siegmund Missall
Place and date: Aksu, November and December 2011

(The interview series originally focused on the urban green of Aksu, but many interviewees

685 made spontaneous contributions about Kökyar Protection Forest.)

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745 Table 1: Overview of the present four project periods of Kökyar Protection Forest. Bold numbers: sums of single project areas; italic numbers: provisional figures of the planned extent.

Kökyar project period	Time frame	Total area [ha]	Shelterbelt area [ha]	Orchard area [ha]	Shelterbelt area [%]	Orchard area [%]
Kökyar I	1986-1990	<u>1308</u> ^{1,308}	686	623	52	48
		⁸				
Kökyar II	1991-1998	<u>1001</u> ^{1,001}	423	578	42	58
		¹				
Kökyar III	1999-2005	<u>1533</u> ^{1,533}	153	<u>1380</u> ^{1,380}	10	90
		³				
Kökyar I-III	1986-2005	<u>3842</u> ^{3,842}	<u>1262</u> ^{1,262}	<u>2580</u> ^{2,580}	33	67
		^{2}				
<i>Kökyar IV</i>	<i>2006-2010</i>	<i>10,000</i>				
<i>Kökyar I-IV</i>	<i>1996-2010</i>	<i>13,842</i>				

Table 2: The establishment costs of Kökyar I.

Cost item	Initial investment costs [million CNY/RMB]	Adjusted for inflation (2014) [million CNY/RMB]	Calculated per area ¹ [CNY/RMB ha ⁻¹]	Share of total [%]
Management (surveying, planning, organising, etc.)	(unknown)	(unknown)	(unknown)	
Bulldozing (and other heavy earthworks)	2.351	7.989	57455,745	9
Water engineering (including all tasks of the River Management Department)	7.538	21.516	15,480	25
Road construction (asphalt and earth roads)	4.387	12.523	90159,015	15
Drinking water facilities	(unknown)	(unknown)	(unknown)	
Cable system (power lines and telephone lines)	0.807	2.302	16501,650	3
Afforestation (including all tasks of the Prefectural Forestry Department)	2.800	9.441	67956,795	11
Compulsory labour	11.347	31.324	22,545	37
TOTAL	29.463	85.095	61,245	100

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¹ Calculating with the overall area size of Kökyar I, which slightly exceeds the afforested area of Kökyar I (cf. Kökyar Annals Compilation Committee, 1996).

Table 3: Comparison of initial investment costs between Kökyar I and partial areas of Kökyar III, excluding costs of compulsory labour.

Area denomination	Initial investment costs [million CNY/RMB]	Adjusted for inflation (2014) [million CNY/RMB]	Area size [ha]	Initial investment costs [CNY/RMB ha ⁻¹]
Kökyar I	18.116	53.771	1389 1,389 ²	38,700
Zhang Lianzhi (part of Kökyar III)	7.000	10.006	333	30,015
13 investors (part of Kökyar III)	30.000	42.734	1200 1,200	35,205

755

² Calculating with the overall area size of Kökyar I, which slightly exceeds the afforested area of Kökyar I (cf. Kökyar Annals Compilation Committee, 1996).

Table 4: Annual wind-borne sand events in the region of Aksu City 1954 to 1990.

Time frame	Aksu City	Onsu County Town	Fifth Corps
1954 – 1980	11.9	5.6	16.5
1981 – 1986	10.8	5.3	22.2
1987 – 1990	4.3	1.0	20.5

760 Table 5: Averaged annual incomes and costs of Kökyar I farmers.

Income and cost item	Adjusted for inflation (2014) [CNY/RMB ha ⁻¹]
GROSS INCOME	
a) Good harvest (2010)	86,524
b) Bad harvest (2011)	42,823
c) Long-term average (acc. Kökyar Annals)	78,704
COSTS	
Lease	8,979
Irrigation	1,324
Compulsory labour	1,074
Fertilisers	11,521
Pesticides	5,375
Machines and diesel	1,120
Harvest hands	3,465
NET INCOME	
a) Good harvest (2010)	55,166
b) Bad harvest (2011)	11,465
c) Long-term average (acc. Kökyar Annals)	47,376

Table 6: Averaged net incomes per working day of Kökyar I farmers.

Income situation	Adjusted for inflation (2014) [CNY/RMB day ⁻¹]
Good harvest (2010)	306
Bad harvest (2011)	64
Long-term average (acc. Kökyar Annals)	263

Tabelle 7: Annual incomes and costs of the Water and Forest Management Station for Kökyar I.

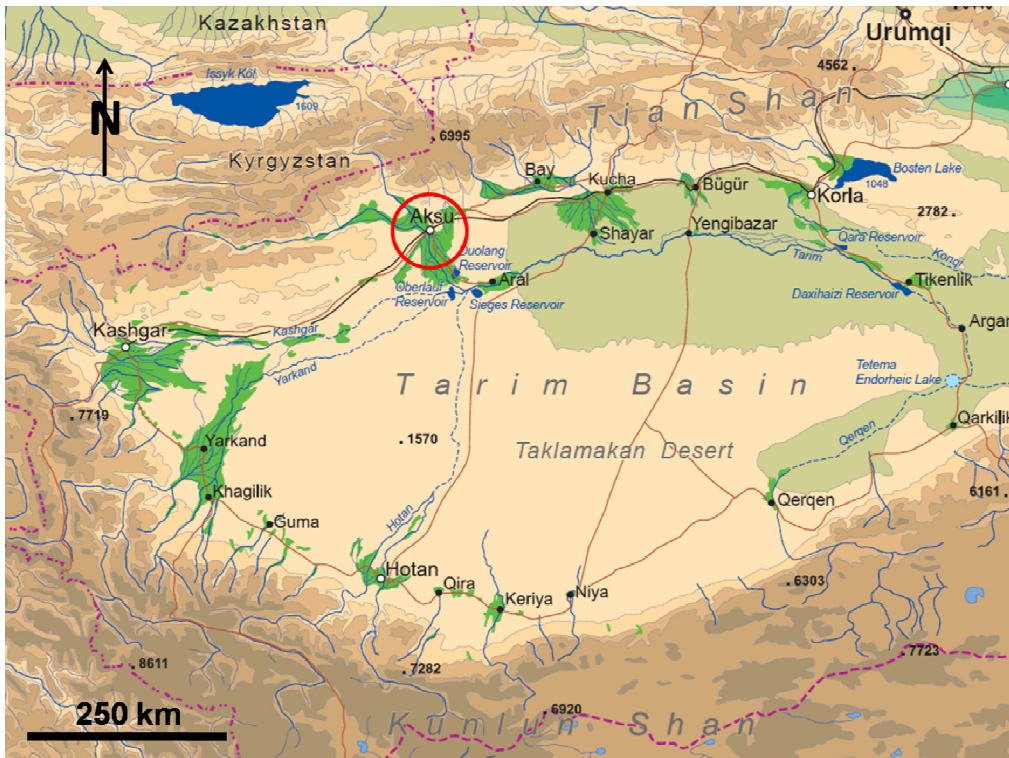
Income and cost item	Adjusted for inflation (2014) [million CNY/RMB]
GROSS INCOME	
Lease income	5.024
Irrigation water income	0.740
Timber	4.785
COSTS	
Total costs	19.215
NET INCOME	
Loss, covered by regular government grants	-8.665

Table 8: Annual benefits and costs of Kökyar I from the perspective of local economy.

Benefit and cost item	Adjusted for inflation (2014) [million CNY/RMB]
GROSS BENEFITS	
Fruit harvests (long-term average)	44.038
Timber	4.785
Lease income	5.024
Irrigation water income	0.741
COSTS	
Lease payments	5.024
Irrigation water fees	0.741
Compulsory labour	0.601
Fertilisers	6.447
Pesticides	3.008
Machines and diesel	0.627
Harvest hands	1.939
Opportunity costs of farm work	5.198
Expenses of the governmental organisations	19.215
NET BENEFIT	
Annual financial net benefit for the local economy	11.789

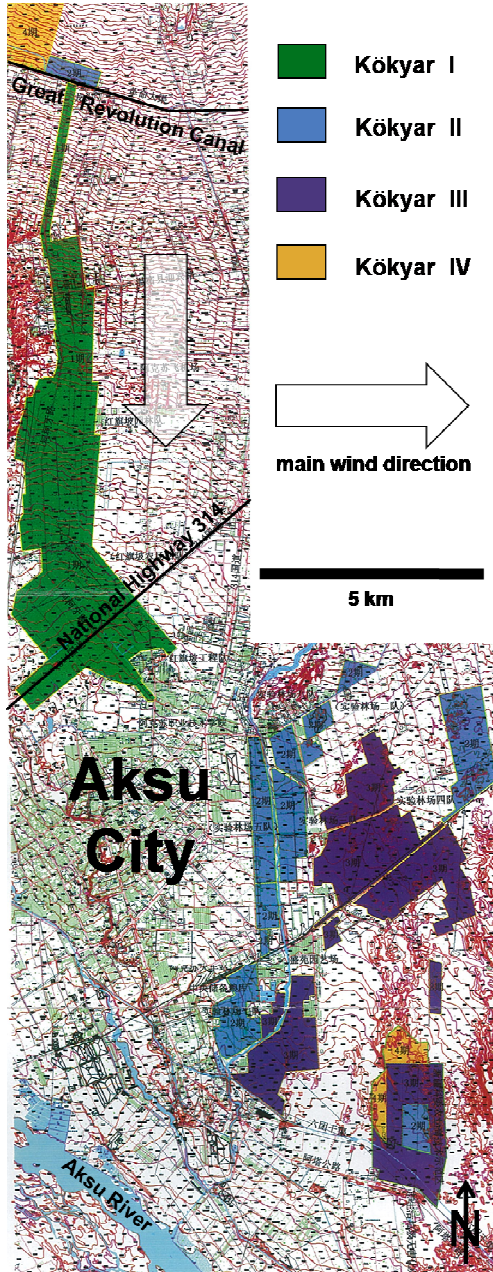
Figure 1: Geographic position of Aksu City in the Tarim Basin, northwest China (adapted from Paproth and Pietsch, 2011).

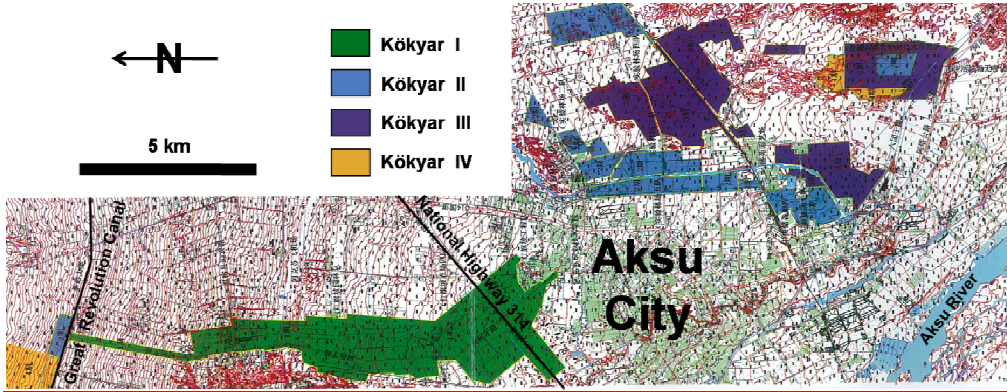
Feldfunktion geändert



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Figure 2: The project areas of Kökyar I, II, III, and IV (partial view; adapted from Kökyar Annals
| Compilation Committee, 2006).
|



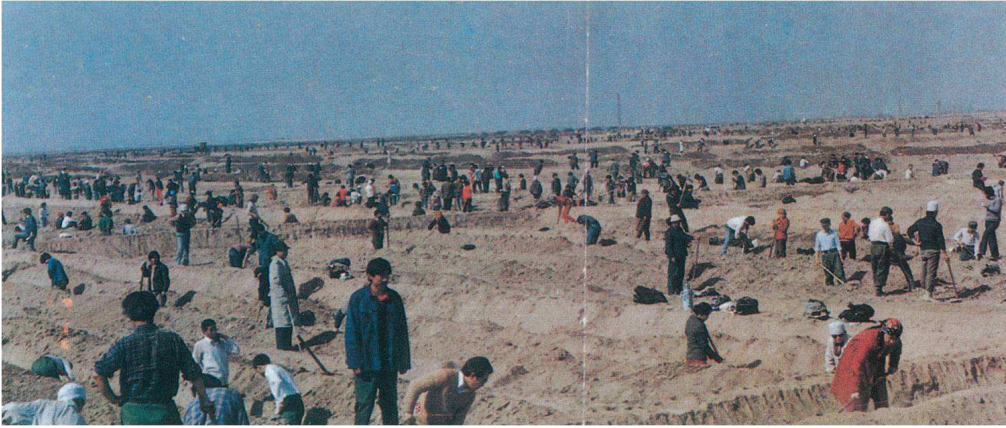


Formatiert: Abstand Nach: 0 pt,
Zeilenabstand: Doppelt

Figure 3: Aerial view of the northern edge of Kökyar I (adapted from Aksu Prefectural Greening Committee, 2006).



785 Figure 4: Compulsory labour on the Kökyar fields (adapted from Kökyar Annals Compilation Committee, 1996).



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Figure 5: Graphic summary of the cost and benefit flow of Kökyar I (red arrows representing costs, black arrows monetary benefits).

