Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

Earth System Dynamics Discussions
Open Access
EGU

Climate and resource information as tools for dealing with farmer-pastoralist conflicts in the Sahel

Ole Mertz[1], Kjeld Rasmussen[1], Laura Vang Rasmussen[1,2]

[1]Department of Geosciences and Natural Resource Management, University of Copenhagen, 1350 Copenhagen K, Denmark
[2]International Forestry Resources and Institutions (IFRI), School of Natural Resources & Environment, University of Michigan, Ann Arbor, USA

Correspondence to: Ole Mertz (om@ign.ku.dk)

Abstract. Conflicts between pastoralists and farmers in the Sahel arise from competition over land and water resources or because of livestock damages to crops. Rather than being linked to larger environmental change processes such as climate change, they are often caused by inappropriate zoning of land, governance and unequal power relations between stakeholders in the conflicts. In this paper, we explore if improved weather and resource information and improvement in its communication could prevent conflicts or reduce their severity. Based on a survey of key stakeholders and studies on pastoral access to and use of information, we conclude that improved information may both reduce and increase the level of conflict, depending on the context. Communication of improved information will need to go beyond just the weather and resource information and also include the multiple options for herd movements as well as providing information on herd crowding and potential conflict areas.

1 Introduction

The history of conflicts involving pastoralists and farmers in the West-African Sahel is long. Conflicts arise from agricultural encroachment on land and pastures traditionally used by pastoralists, or are associated with livestock damages on crops in rain-fed fields and in irrigated gardens. Moreover, there are also classic conflicts between pastoralists on the access to and use of pastures and watering points (wells, boreholes). Especially in the dry season, when prices for accessing water can be high, conflicts may intensify. These conflicts often receive more attention than the well-known symbiotic relationships whereby farmers and pastoralists exchange crop residues and manure. In addition, herders and farmers are very heterogeneous and overlapping categories, both in terms of production systems, social organization and ethnicity. Across the Sahel, livestock is to an increasing extent owned by groups that are not usually considered to be pastoralists, and groups that are traditionally considered to be pastoralists are increasingly becoming involved in farming and other economic activities (Hesse, 2011), adding to the complexity of conflicts (Beeler, 2006).

Numerous more or less simplistic explanations of the farmer-pastoralist conflicts have been suggested in the scientific literature (see overviews of this large literature by Hussein et al., 1999; Turner, 2004; Turner et al., 2011; Benjaminsen,

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

2016). In recent years, for example, it has been claimed in various political arenas that climate change has caused – or aggravated – conflicts, due to its alleged negative impacts on resource availability. Closer examination of these claims have largely caused them to be refuted as the root causes of conflicts are found in socio-political events and conditions such as inadequate land policies and rent-seeking (Benjaminsen et al., 2012; Benjaminsen, 2016). Some studies do show that extreme weather events – whether triggered by climate change or not – may exacerbate existing conflicts (Raleigh and Kniveton, 2012), but the fact that climate variability is perceived to have a much lower impact on livestock productivity in areas where zoning of pastoral lands are implemented and enforced indicates that climate factors are secondary to policy drivers (Mertz et al., 2010).

Whatever the reason behind, farmer-pastoralist and pastoralist-pastoralist conflicts prevail in many areas in the Sahel. The underlying causes may be social, political or economic, but the direct drivers of specific conflicts are mostly a result of competition for concrete land areas, certain types of vegetation and water resources used for both farming and livestock. As all of these resources are influenced by climate variability, one may hypothesize that better information on the state and changes in resources, and on the weather patterns that influence them, would be useful for mitigating conflicts, at least in the short term and even if it only would be treating the 'symptoms' rather than their root causes.

Hardly any attention has, however, been devoted to what role information about climate, weather, and natural resources might play for conflict resolution. This is surprising as both pastoralists and farmers have been shown to act upon the information available to them and are indeed able to understand more complex probabilistic forecasts, including the risks associated with following recommendations on for example sowing dates and length of the rainy season (Ingram et al., 2002; Roncoli et al., 2009; Rasmussen et al., 2015). A study in Senegal showed, on the other hand, that pastoralists are reluctant to support information sharing about pastures (Kitchell, 2016). Reasons include that pastures become a 'common property' and this may compromise their priority access to certain areas, potentially creating additional conflict. Yet, this was not found in northern Burkina Faso, where there was a demand for information and criticism was more directed at its value and the forms of communication (Rasmussen et al., 2014; Rasmussen et al., 2015). In any case, when people are faced with increasing climate variability, their actions and management strategies will most likely differ depending on the level of knowledge gained about the weather and the resource availability. The question remains whether this knowledge will mitigate or exacerbate conflicts when decisions about resource use and mobility are made.

In the present paper, we discuss the possible linkages between resource conflicts and various information dissemination systems. For example, we look into dissemination systems based on information from satellite data, traditional forecasting methods, and seasonal forecast models. The question asked is whether such information systems, apart from being useful as a basis for day-to-day decisions, will tend to lessen or increase competition for resources and thus the potential for conflicts. We use the limited existing literature to assess the role of information and complement this with a short questionnaire survey

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

among local government and private stakeholders involved in dissemination of climate and resource information. The latter involved a questionnaire distributed to staff from key dissemination institutions in West Africa, including provincial agricultural and meteorological services and radio stations in Burkina Faso, Mali and Niger. The survey was conducted during the "Workshop on the dissemination of agro-hydro-climatological information to final users in the project Knowledge Based Climate Adaptation in West Africa (Original French title: Atelier de Diffusion et de Dissémination de l'Information Agro-Hydro-Climatique aux Usagers Finaux du Projet ACCIC), held in Ouagadougou, Burkina Faso, 3-5 December 2015. A total of 24 participants took part in the survey. Sixteen participants responded to the questionnaire that requested information on their knowledge of cases where resource or climate information had contributed to resolving or aggravating conflicts and on their opinion on the role of information as a conflict resolution tool, including how this can take place. In addition to the survey, notes were taken of discussions during the workshop to capture opinions and more nuanced details in views on information systems and their dissemination among farmers and pastoralists.

Before moving to the results of the survey, we start by identifying the information needs of pastoralists as they have been largely neglected as recipients of resource information (Rasmussen et al., 2014; Rasmussen et al., 2015). We then discuss implications of the results for farmer-pastoralist conflict resolution and development of appropriate information systems in the Sahel.

2 Information needs of pastoralists

Pastoral societies still rely to a large extent on traditional agricultural and livestock production methods even though the sector to an increasing extent has become a supplier of meat to the coastal regions of West Africa, and thus partly commercialized. As pastoralists are becoming sedentary in many parts of the Sahel, such as the Ferlo of northern Senegal, the competition for land and resources in nearby areas gets more pronounced because pastoralists still rely on varying degrees and types of herd mobility (Adriansen and Nielsen, 2005). Ensuring appropriate and efficient mobility of livestock is thus the key element for which pastoralists need information about the state and expected changes in climate, weather, and resources. Rasmussen et al. (2014) discuss the demand for information among pastoralists on the basis of field work in northern Burkina Faso and find that pastoralists seek information that would facilitate more informed decision-making on herd management. These include the location of the herd in order for it to thrive and make the best of current – and expected future – vegetation and water resources as well as information on markets for selling livestock and purchasing feed and veterinary services, especially if there are expectations of insufficient future availability in pastures and water.

The basis upon which these decisions are taken by pastoralists includes experience from the past, own observations, e.g. signs indicating the arrival of the monsoon and information from family members, friends or hired scouts on vegetation and water resources – as well as prices – often conveyed by mobile phone (Rasmussen et al., 2015; Kitchell, 2016). These

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

traditional information systems are now being complemented by satellite-based information on weather and resource availability, but the role of these new technologies – as well as the full potential of mobile phone technologies – in this decision making process and for preventing or resolving conflicts has yet to be fully explored.

2.1 Information on climate variability and seasonal forecasts

Weather patterns and climate variability are of course very important for the availability of vegetation and water resources and improvements in this information on this could be potentially beneficial for pastoralists. The long term effects of climate change that will lead to increasing temperatures and fewer but more violent rainfall events (Niang et al., 2014) will of course be relevant for the future survival of pastoralism and farming (Lambin et al., 2014), especially if the observed trends in August rainfall anomalies in August, a crucial months for crops and vegetation, continue (Mertz et al., 2012; Nicholson, 2013). However, short term seasonal forecasts are more useful for farmers and pastoralists. Since 1998, the Climate Outlook Forum PRESAO (PREvisions Saisonnières en Afrique de l'Ouest) has created seasonal rainfall forecasts (Tarhule and Lamb, 2003; Patt et al., 2007). Such forecasts are mostly seen as an input to farmers' choices of which fields to cultivate and which crops or crop varieties to cultivate. Although farmers, as mentioned above, have been shown to use seasonal forecasts rationally, relatively few farmers do so (Ingram et al., 2002; Ingram et al., 2008; Roncoli et al., 2009; Roudier et al., 2014), probably because of the inaccessibility of the information. The forecasts are therefore mostly used for national planning purposes and early warnings of crop failure. Analogously, pastoralists' use of seasonal forecasts appears very limited in the Sahel (Rasmussen et al., 2014).

2.2 Information on vegetation resources

Vegetation information may be provided by field observation or by satellite-based remote sensing. Obviously, pastoralists themselves monitor vegetation resources and share this information, often using mobile phones but this information is limited in spatial extent and completeness. A number of methods for satellite-based monitoring of vegetation productivity in the Sahel have been developed and could be potentially useful for pastoralists. The current standard methodology is based on analysis of time-series of coarse resolution satellite images, mostly from NOAA AVHRR, SPOT Vegetation and MODIS, using the normalized difference vegetation index (NDVI) as a proxy for vegetation productivity. Mbow et al. (2013) show that NDVI is sensitive to the species composition, limiting its precision for assessment of fodder production. While in cropped areas the summed NDVI is correlated to crop yield and therefore useful in early warning systems of crop failure, outputs from such monitoring systems are of limited value to pastoralists. For pastoralists the end of the rainy season is the most critical period of the year for pastoralists as they must make decisions on herd location, selling of livestock, splitting of herds etc. based on information on dry season fodder resources. Unfortunately, satellite-based methods for providing information on available non-green fodder resources in near real-time and with the necessary spatial detail are not presently operational and a suitable method for distributing such information would also have to be developed.

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

2.3 Information on water resources

Pastoralists also need real-time information on water availability in day-to-day decisions, especially during the dry season when ponds and lakes progressively dry out and only water from wells and boreholes is available. This can be provided by remote sensing methods that use high resolution satellite images for monitoring the gradual drying out of surface water resources. However, as wells and boreholes are not always operational, especially those that are operated by pumps that require maintenance, information on access to, and availability and price of water is therefore also crucial, and is presently seldom collected and broadcasted widely. A 'pastoral decision-support system' would ideally integrate such information, including information on the physical availability and on the management of the resources.

2.4 Other information types: herd location and markets

Herding decisions are not only based on information on weather and availability of resources but also involve knowledge of – or expectations of – the competition for these resources from herds other than your own. Such information is not publicly available and is therefore obtained through informal networks of family and friends, mostly by mobile phones. Moreover, as pastoralism becomes increasingly commercialized, decisions are to a greater extent guided by economic criteria, e.g. livestock prices and prices on supplementary feed. Such market information is nowadays available to a substantial part of the pastoralists through the same informal networks based on mobile phones that are gaining increasing importance as the key distribution method.

2.5 Communication of information to pastoralists: new communication technology

When satellite-based crop/vegetation monitoring was first introduced in the 1980s, the information, e.g. in the form of maps of NDVI, was presented to end-users, such as pastoralists, by radio and television broadcast. Obviously, the impact on pastoralist decision making was quite limited. The main users of previous efforts to disseminate information, such as the Famine Early Warning System Network (FEWS NET), were primarily government agencies and international donors involved in food relief (Boyd et al., 2013). As mobile phones have become widespread in West Africa, information distribution – and especially the speed of distribution – has been transformed, and this needs to be included in new strategies for dissemination of weather and resource information, especially for pastoralists who rely on mobile phones more than any other sector in rural West Africa (Rasmussen et al., 2015). While 'smart-phone' technology may provide a promising avenue for delivering spatially detailed information, their use may, however, be limited in the Sahel. Reasons include that the presentation of information to pastoralists that are illiterate and do not have full command of national languages will require careful consideration in order to avoid mis-interpretation and inequality in access to the information (Rasmussen et al., 2015). Moreover, use of 'smart-phones' rather than traditional mobile phones, will demand more frequent charging, which might prove difficult in remote pastoral communities unless its use is supported by technological development of solar-panel based chargers and/or by battery charging becoming a widely available commercial service.

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

3. Conflicts and the role of climate and resource information

As mentioned above, very few studies have explored whether climate and resource information can be used as a tool for resolving conflicts or whether indeed better availability of this information may aggravate conflicts.

3.1 Results of survey with dissemination stakeholders

The 16 respondents from the workshop on dissemination provided a somewhat diverse picture on the role of information for conflicts. Three respondents were not aware of concrete cases where climate or resource information had played a role in conflict resolution or aggravation, but the remaining 13 provided a total of 16 combinations of information types and conflict outcomes (Figure 1). Most respondents provided cases, where information resolved conflicts, which may not be so surprising given the role that these agencies play in disseminating this type of information. However, there were exceptions and these were particularly related to information on water and vegetation resources that could lead to aggravation of conflicts. The cases described were quite diverse and, in the words of respondents, included:

> "*Biomass and water information to pastoralists will make them move to favorable areas, provoking conflicts both with farmers and other pastoralists. This is caused by lack of areas for free passage of cattle and because of competition for water in wells*";
>
> "*Too early movement of animals both north to south and south to north caused conflicts in transition zones*";

These are thus both cases of correct information that lead to clashes between farmers and pastoralists as well as among pastoralists since favorable areas had either not been adequately zoned to receive such a large amount of livestock and cases where wrong information to farmers led to cultivation in areas less suitable for cultivation, but were livestock would graze during the rainy season.

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

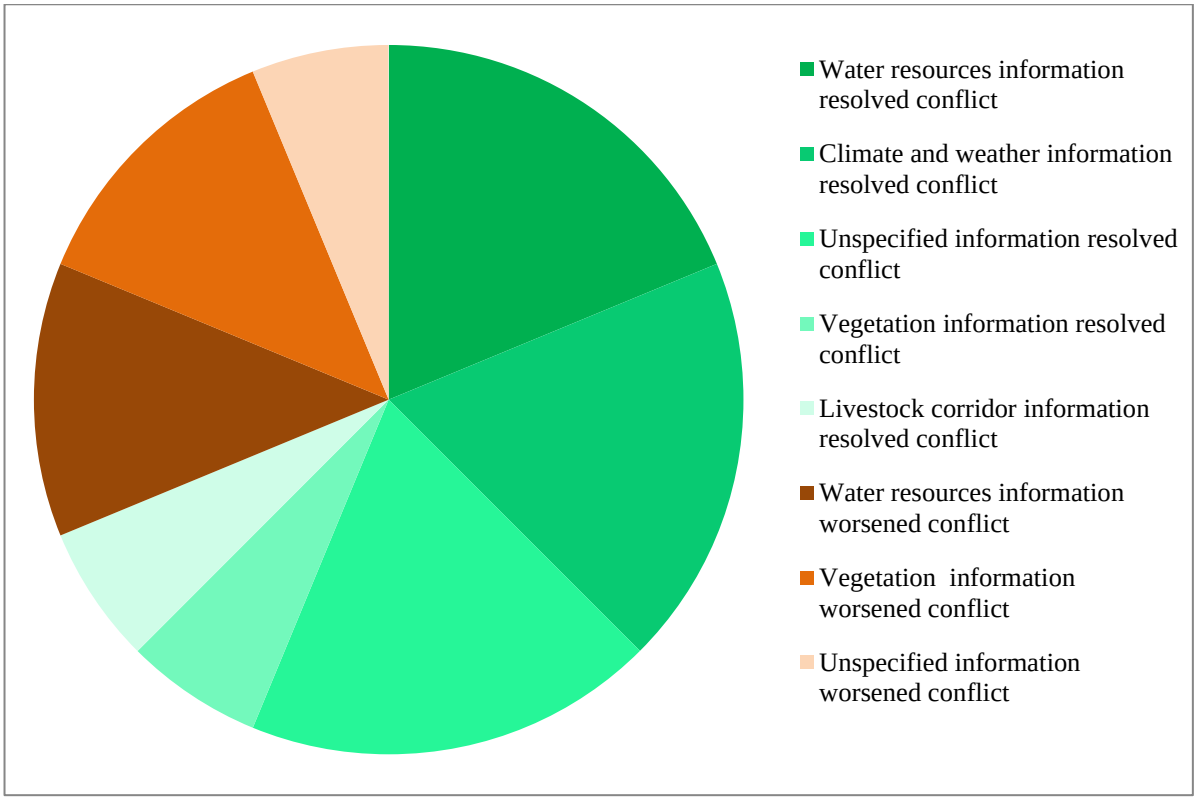

Figure 1. Distribution of responses on which types of information may lead to conflict resolution or aggravation as experienced by staff from provincial agricultural and meteorological services and from radio stations in Burkina Faso, Mali and Niger. N=16 (13 respondents provided answers, three provided information on two information categories. Source: questionnaire distributed at "Workshop on the dissemination of agro-hydro-climatological information to final users in the project Knowledge Based Climate Adaptation in West Africa, 3-4 December 2015".

Interestingly, the survey revealed a new type of conflicts arising from information dissemination: conflicts between farmers and institutions. It was for example expressed that "*Flooding forecasts led farmers to sow on higher and more dry lands and dry spells then caused yields to decline. This caused the farmers to criticize the meteorological department*". Besides lower yields, the expansion into drylands also led to disruption of livestock corridors. This statement highlights the issue of communicating the uncertainty related to the information as uncertain information clearly leaves great room for misunderstanding and miscommunication of risks which can have huge repercussion for pastoralists and farmers' livelihood.

The larger number of responses related to positive impacts of information on conflict resolution was also illustrated by explanations such as:

> "*Information given on reduced water level in a dam allowed farmers and pastoralists to agree on the water management and use in the dam*";

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

Earth System Dynamics Discussions
Open Access
EGU

"*[Agro-meteorological] information helps pastoralists choose itineraries that avoid newly sown areas by farmers and help farmers avoid planting in livestock corridors*"

"*Information on timing of retracting waters in Lac Chad gives pastoralists the option to avoid islands, where farmers start cultivating*"

Moreover, respondents when asked whether improved information on climate and resources in certain contexts could assist in conflict resolution, all respondents that provided answers said yes. They illustrated the answers partly with their comments to the previous questions but also elaborated:

"*If information is given so that pastoralists have a variety of options, then they can plan and diversify their movements to avoid all going to the same places. Pastoralists need to have their own information dissemination system improved through proper participation in information system development*"

"*Continued information on and zoning of pasture, livestock corridors, watering areas are needed to avoid further conflicts*"

"*Improvement of the use of mobile phones and other new technologies accessible to pastoralists*"

"*Feed-back to information providers of information needs to be systematic necessary for the systems to get better*"

There was thus a strong emphasis on developing information systems that build on traditional ways of communication information and ensure the participation of pastoralists in their conception as well as for feeding back actual on-site information on resources and weather to improve the information provided. The use of mobile phone technologies was not seen as an obstacle at all as they have already been appropriated by pastoralists.

There was among representatives from the radio stations a strong and not surprising emphasis on the use of radio transmissions as a way to disseminate information and thus also to contribute to the prevention of conflicts. However, with the exception of Mali, where radio broadcasts were mentioned to have alleviated concrete conflicts, it was not possible to establish whether radio is the best tool to address this issue.

3.2 Perspectives for climate and resource information to contribute to resolving conflict

The participants in the workshop all agreed during discussions that there is a need to improve both the quality of information and how it is disseminated as conflicts that could possibly have been avoided, still occur. It is thus evident that farmers and pastoralists in the Sahel make decisions on their use of natural resources on the basis of incomplete information, both about current conditions, e.g. on the spatial distribution of resources, and about probabilities of future events, e.g. the rainfall in the coming rainy season or next year's livestock prices. In this section we therefore discuss the possible consequences of making information on current and future resources more tailored to the needs of pastoralists as a user group, including how it may influence the occurrence of conflicts involving pastoralists.

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

If it would be possible to produce real-time, spatially explicit information on availability of fodder and water resources (particularly in the dry season) and distribute this to pastoralists, e.g. in graphical form by smart-phone or as voice messages in local languages on an automated phone services as suggested by (Rasmussen et al., 2015). Access to and prices of water are also important for decision making and information on all these elements would most likely affect decisions concerning location (and possibly splitting) of herds and it would reduce the probability of making inappropriate short term decisions which might cause increased livestock mortality, economic losses, and conflict with farmers and other pastoralists (Hesse, 2011).

In principle, we could thus envision a situation where all pastoralists have identical, real-time information about where vegetation and water resources are currently available, and about the access to and price of water resources. As mentioned by the workshop respondents, this may lead many pastoralists to pursue similar strategies, potentially causing increased risk of over-use and subsequent resource depletion and conflict if all descend on the same areas. However, it may also allow pastoralists to obtain information about more options than they otherwise would have had and thus contribute to spreading herds more and thus lowering pressure in each area. The question is thus simply whether a structured satellite-based information system could provide, if not better, more information across larger areas than the traditional systems or whether it will just result in more people hearing about a limited number of favorable areas, creating more crowding than previously. Or perhaps the traditional pastoral information systems are already sufficiently efficient in capturing all available resources and a new system will not make any difference. The only way to answer these questions will of course be to increase the knowledge base on the information-conflict link between farmers and pastoralists.

As mentioned in the introduction, it is in any case clear that better information will not be enough to solve conflicts between farmers and pastoralists and among pastoralists. The underlying causes for conflicts are most often related to land policies and (Benjaminsen et al., 2012; Benjaminsen, 2016) and implementation and enforcement of pastoral land zoning are probably some of the best ways to reduce the number conflicts as it will clarify land uses for all groups (Mertz et al., 2010; Hesse, 2011). While such land use policies have been implemented in many of the silvo-pastoral zones of the Sahel, they are much less prevalent in the more semi-arid and sub-humid zones dominated by farming and it is often in these areas that conflicts arise when pastoralists search for dry season pastures and water resources. Empowerment of pastoralists and pastoral organizations that allows them to influence land use policies would, among other things, involve assuring equitable access to information and in that sense better climate and resource information could perhaps play a role for increasing the general information level of pastoralists by placing them in a stronger position to argue for their rights to the traditional pastures in predominantly agricultural zones.

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

4. Conclusions

Sahel has for centuries been a scene for fierce competition for land and natural resources, both among pastoralists and between pastoralists and farmers. The great variability in time and space of resource availability requires pastoralists to take decisions on the basis of incomplete information, sometimes with negative outcomes. Use of modern technologies such as satellite-based earth observation to collect and mobile phones to distribute information on weather, climate variability, vegetation and water resources could be promising for reducing the conflicts that arise over land and access to pasture. However, more information may also lead to increased conflict in some cases if it is not managed or communicated in a way that will avoid to many herds descending on areas that are too limited in size.

The design of the information systems therefore should not only provide actual improvements in access to real-time, spatially explicit weather and resource information. They should also integrate elements such as areas with potential herd crowding and in general be developed with the participation of pastoral communities in order to better target the most pressing needs.

References

Adriansen, H., and Nielsen, T.: The geography of pastoral mobility: A spatio-temporal analysis of GPS data from Sahelian Senegal, GeoJournal, 64, 177-188, 2005.

Beeler, S.: Conflicts between farmers and herders in north-western Mali, IIED Issue Paper no. 141, IIED, London, 2006.

Benjaminsen, T. A., Alinon, K., Buhaug, H., and Buseth, J. T.: Does climate change drive land-use conflicts in the Sahel?, Journal of Peace Research, 49, 97-111, 10.1177/0022343311427343, 2012.

Benjaminsen, T. A.: Does Climate Change Lead to Conflicts in the Sahel?, in: The End of Desertification? : Disputing Environmental Change in the Drylands, edited by: Behnke, R., and Mortimore, M., Springer Berlin Heidelberg, Berlin, Heidelberg, 99-116, 2016.

Boyd, E., Cornforth, R. J., Lamb, P. J., Tarhule, A., Lele, M. I., and Brouder, A.: Building resilience to face recurring environmental crisis in African Sahel, Nature Clim. Change, 3, 631-637, 10.1038/nclimate1856, 2013.

Hesse, C.: Natural resource management in pastoral systems. Chapter 4 in (2011): . . , in: New Perspectives on Natural Resource Management in the Sahel, edited by: Bolwig, S., Rasmussen, K., Hesse, C., Hilhorst, T., and Hansen, M. K., SEREIN Occasional Papers no. 17, Copenhagen, 51-88, 2011.

Hussein, K., Sumberg, J., and Seddon, D.: Increasing Violent Conflict between Herders and Farmers in Africa: Claims and Evidence, Development Policy Review, 17, 397-418, 10.1111/1467-7679.00094, 1999.

Ingram, J. S. I., Gregory, P. J., and Izac, A. M.: The role of agronomic research in climate change and food security policy, Agriculture, Ecosystems & Environment, 126, 4-12, 2008.

Ingram, K. T., Roncoli, M. C., and Kirshen, P. H.: Opportunities and constraints for farmers of west Africa to use seasonal precipitation forecasts with Burkina Faso as a case study, Agricultural Systems, 74, 331-349, 2002.

Kitchell, E.: Information sharing and climate risk management among Senegalese agropastoralists, Climate and Development, 8, 158-168, 10.1080/17565529.2015.1034225, 2016.

Lambin, E. F., Mertz, O., Rasmussen, K., Reenberg, A., D'haen, S., and Nielsen, J. Ø.: Scenarios on the future of the African Sahel, Geografisk Tidsskrift-Danish Journal of Geography, 114, 76-83, 2014.

Mbow, C., Fensholt, R., Rasmussen, K., and Diop, D.: Can vegetation productivity be derived from greenness in a semi-arid environment? Evidence from ground-based measurements, Journal of Arid Environments, 97, 56-65, http://dx.doi.org/10.1016/j.jaridenv.2013.05.011, 2013.

Mertz, O., Mbow, C., Nielsen, J. Ø., Maiga, A., Diallo, D., Reenberg, A., Diouf, A., Barbier, B., Moussa, I. B., Zorom, M., Ouattara, I., and Dabi, D.: Climate factors play a limited role for past adaptation strategies in West Africa, Ecology and Society, 15, Article 25, 2010.

Mertz, O., D'haen, S., Maiga, A., Bouzou Moussa, I., Barbier, B., Diouf, A., Diallo, D., Da, E. D., and Dabi, D.: Climate variability and environmental stress in the Sudan-Sahel zone of West Africa, Ambio, 41, 380-392, 2012.

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J., and Urquhart, P.: Africa, in: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Barros, V. R., Field, C. B., Dokken, D. J., Mastrandrea, M. D., Mach, K. J., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., and White, L. L., Cambridge University Press, Cambridge, UK and New York, USA, 1199-1265, 2014.

Nicholson, S. E.: The West African Sahel: A Review of Recent Studies on the Rainfall Regime and Its Interannual Variability, ISRN Meteorology, 2013, 32, 10.1155/2013/453521, 2013.

Patt, A. G., Ogallo, L., and Hellmuth, M.: SUSTAINABILITY: Learning from 10 Years of Climate Outlook Forums in Africa, Science, 318, 49-50, 2007.

Raleigh, C., and Kniveton, D.: Come rain or shine: An analysis of conflict and climate variability in East Africa, Journal of Peace Research, 49, 51-64, 10.1177/0022343311427754, 2012.

Rasmussen, L. V., Mertz, O., Rasmussen, K., Nieto, H., Ali, A., and Maiga, I.: Weather, Climate, and Resource Information Should Meet the Needs of Sahelian Pastoralists, Weather, Climate, and Society, 6, 482-494, 10.1175/WCAS-D-14-00010.1, 2014.

Rasmussen, L. V., Mertz, O., Rasmussen, K., and Nieto, H.: Improving how meteorological information is used by pastoralists through adequate communication tools, Journal of Arid Environments, 121, 52-58, http://dx.doi.org/10.1016/j.jaridenv.2015.05.001, 2015.

Roncoli, C., Jost, C., Kirshen, P., Sanon, M., Ingram, K., Woodin, M., Somé, L., Ouattara, F., Sanfo, B., Sia, C., Yaka, P., and Hoogenboom, G.: From accessing to assessing forecasts: an end-to-end study of participatory climate forecast dissemination in Burkina Faso (West Africa), Climatic Change, 92, 433-460, 2009.

Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-21, 2016
Manuscript under review for journal Earth Syst. Dynam.
Published: 17 May 2016

Roudier, P., Muller, B., d'Aquino, P., Roncoli, C., Soumaré, M. A., Batté, L., and Sultan, B.: The role of climate forecasts in smallholder agriculture: Lessons from participatory research in two communities in Senegal, Climate Risk Management, 2, 42-55, http://dx.doi.org/10.1016/j.crm.2014.02.001, 2014.

Tarhule, A., and Lamb, P. J.: Climate Research and Seasonal Forecasting for West Africans: Perceptions, Dissemination, and Use?, Bulletin of the American Meteorological Society, 84, 1741-1759, 10.1175/BAMS-84-12-1741, 2003.

Turner, M. D.: Political ecology and the moral dimensions of "resource conflicts": the case of farmer–herder conflicts in the Sahel, Political Geography, 23, 863-889, http://dx.doi.org/10.1016/j.polgeo.2004.05.009, 2004.

Turner, M. D., Ayantunde, A. A., Patterson, K. P., and Patterson, E. D.: Livelihood Transitions and the Changing Nature of Farmer–Herder Conflict in Sahelian West Africa, The Journal of Development Studies, 47, 183-206, 10.1080/00220381003599352, 2011.