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365

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Stakeholders' contradicting perceptions on the effects of agroforestry and monocropping systems on water use

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Abstract

The involvement of stakeholders in forest management decisions is crucial to the success of these programmes. Consequently, understanding stakeholders' perceptions is relevant for adequate management and development. In this study, the perceptions of key stakeholders are identified and compared concerning the effects of agroforestry and monocropping systems on water use in the farmlands of the Getas-Ngandong forests (10,901 Ha), a teaching forest belonging to Universitas Gadjah Mada, Indonesia. Q methodology was used to identify the variety of stakeholder viewpoints on the effects of farming practice on water use. 17 statements were ranked by 33 respondents along a five-grade approval scale. The methodology revealed a consensus on some hydrological benefits of agroforestry. Beyond this, three distinct perceptions were identified regarding water related to farming practices. The first is that monocropping systems use more water than agroforestry, while the second states the opposite and the third does not assign the extent of water use to specific systems. Stakeholder groups hold contradicting beliefs within and between themselves. It is important, therefore, to identify which perceptions are true and which are based on myths.

Key words: agroforestry, Q methodology, sociohydrology, stakeholder perceptions, water use

INTRODUCTION

Two perspectives on the function of forests

According to the Food and Agricultural Organization (FAO), 53% of Indonesia's land is forested, of which roughly 50% are classified as primary (FAO 2015). However, the deforestation rate is significant, some 18.3% of the country's forest being lost between 1990 and 2012 (Wijaya *et al.* 2015). There is a widespread belief that deforestation is the main cause of floods, declining rainfall and soil deterioration (Bruijnzeel 2004; Marhaento *et al.* 2018). However, the potentially beneficial relationship between forest cover and water yield is strongly questioned and under constant debate (Calder 1998; Ellison *et al.* 2012).

In general, two perspectives can be distinguished on forests and their hydrological aspects, both with the fundamental assertion that trees use water. One view, sometimes referred to as the debate's 'supply-side', suggests that increasing forest cover raises the water yield and improves water availability at regional and/or global scale, because forests act as sponges. In this perspective, tree roots, forest litter, and soil all act as sponges and some even claim that tree roots release water during the dry season that was adsorbed during the wet season. This sponge effect maintains water supplies during the year (Bruijnzeel 2004; Ellison *et al.* 2012; Marhaento *et al.* 2019). In the other view – the 'demand-side' – forests are seen as consumers of water, competing with other uses, such as

Water Practice & Technology Vol 15 No 2
doi: 10.2166/wpt.2020.024

agriculture. It is claimed in this perspective that roots should be thought of as pumps rather than sponges, and that roots do not release water during the dry season but instead remove it for the trees to grow (Hamilton & King 1983). Bruijnzeel (2004) states that there seems to be a growing tendency to emphasise the more negative aspects of forests – for example, their higher water use and inability to prevent extreme floods – rather than their protective values such as enhanced water quality, moderation of most peak flows and carbon sequestration.

These perspectives are outcomes of extensive research undertaken since the middle of the 20th century to try to understand the nature and dynamics of hydrological processes in tropical catchments. A solid body of scientific information is now available for interpreting the relationships between water and forests in tropical regions. However, there are still the two perspectives on the role of forests that sometimes contradict one another. Some authors even attribute debate over the outcome of increased forest cover on water yield to the gap between public perceptions and scientific knowledge (Calder 2002; Gilmour 2014).

Farming systems; agroforestry and monocropping

The FAO (2009) predicts that food production must increase by 70% by 2050 to feed the world's growing population. This could cause several problems, including intensification of existing agricultural practices (Smith *et al.* 2013). More than 30% of Indonesia's land is defined as agricultural, providing many opportunities for optimising agricultural practices (Central Intelligence Agency 2018). This paper will focus on agroforestry and monocropping systems. In agroforestry woody perennials (trees, shrubs, etc.) are grown in association with agricultural crops, pastures, and/or livestock, in a spatial arrangement or rotation, or both (Nair 1993). Monocropping consists of continuously cultivating one type of crop on the same land.

In 2017, the Indonesian government entrusted the Getas-Ngandong forests (10.901 ha), also known as Special Purpose Forest (KHDTK), on Java, to management by Universitas Gadjah Mada (UGM) from 2017 to 2037. The area is used for teak plantations and farming, with both agroforestry and monocropping systems. Figure 1 is a visualisation of these systems in the study area. Currently, farmers are threatened by unreliable water supply, droughts, and floods. It is crucial, therefore, to manage farm water use correctly to maximise productivity and efficiency.

Cannell *et al.* (1996) suggest a hypothesis that agroforestry systems have a higher productivity than monocropping systems when trees acquire resources that the monocrops would not. Agroforestry systems are also believed to provide many ecosystem services and environmental benefits – e.g., regulating soil, air and water quality, and carbon sequestration (Jose 2009; Marhaento *et al.* 2016,

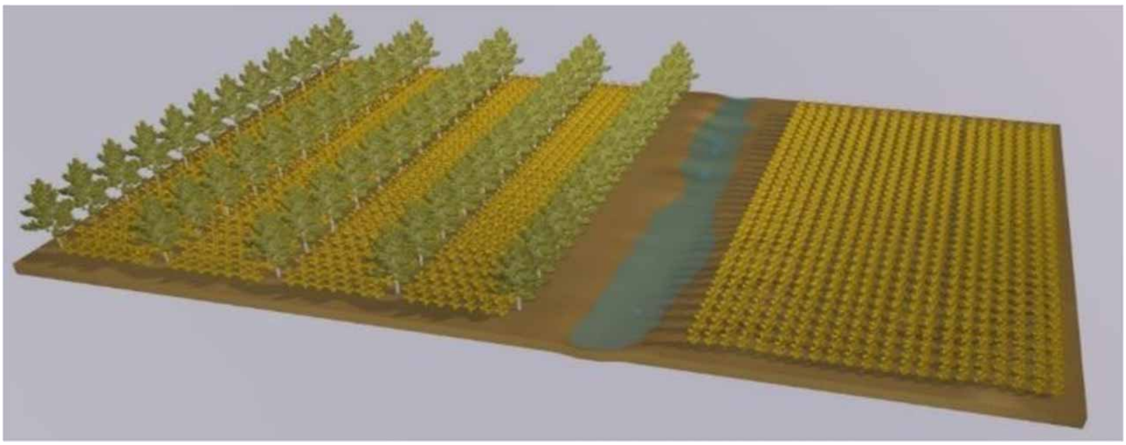

Figure 1 | Agroforestry (left) and monocropping (right).

Water Practice & Technology Vol 15 No 2
doi: 10.2166/wpt.2020.024

2017). Agroforestry is acceptable in sustaining the hydrologic cycle, and providing a reliable tool for soil and water conservation in a watershed (Idris & Mahrup 2017). However, due to the complex relationship between soil water content, rainfall, water uptake by plants and evapotranspiration through the seasons, the water dynamics within agroforestry and monocropping systems are not yet fully understood.

UGM seeks to develop and manage KHDTK by adopting a social forestry strategy, i.e. involving stakeholders to receive the support of all (Yuwono *et al.* 2018). The involvement of stakeholders in forest management is also crucial to the success of these programmes (Silvano *et al.* 2005). It is therefore relevant to have insights into those stakeholders' perceptions on the role of forests and farming systems in water dynamics. The aims of this paper are specifically to explore stakeholder perceptions of the effects of agroforestry and monocropping systems on water use in the KHDTK area.

STUDY AREA

The KHDTK area is in two districts and two provinces, Blora District, Central Java (roughly 80%) and Ngawi District, East Java (roughly 20%). The area contains 15 villages; 9 in Kredenan, Randublatung and Jati subdistricts in Blora District, and 6 in Pitu Subdistrict, Ngawi. The study area for this project consists of the Getas and Pitu village area (Figure 2). These villages were chosen because the farmers cultivate their crops in different ways and the villages are in different districts. Table 1 is an overview of the villages' administrative regions. The populations of both Getas and Pitu were almost 5,000 in 2015, most of whom (83%) were farmers and farm laborers cultivating crops or with livestock. Others were civil servants, private employees, entrepreneurs, and non-agricultural workers (Yuwono *et al.* 2018).

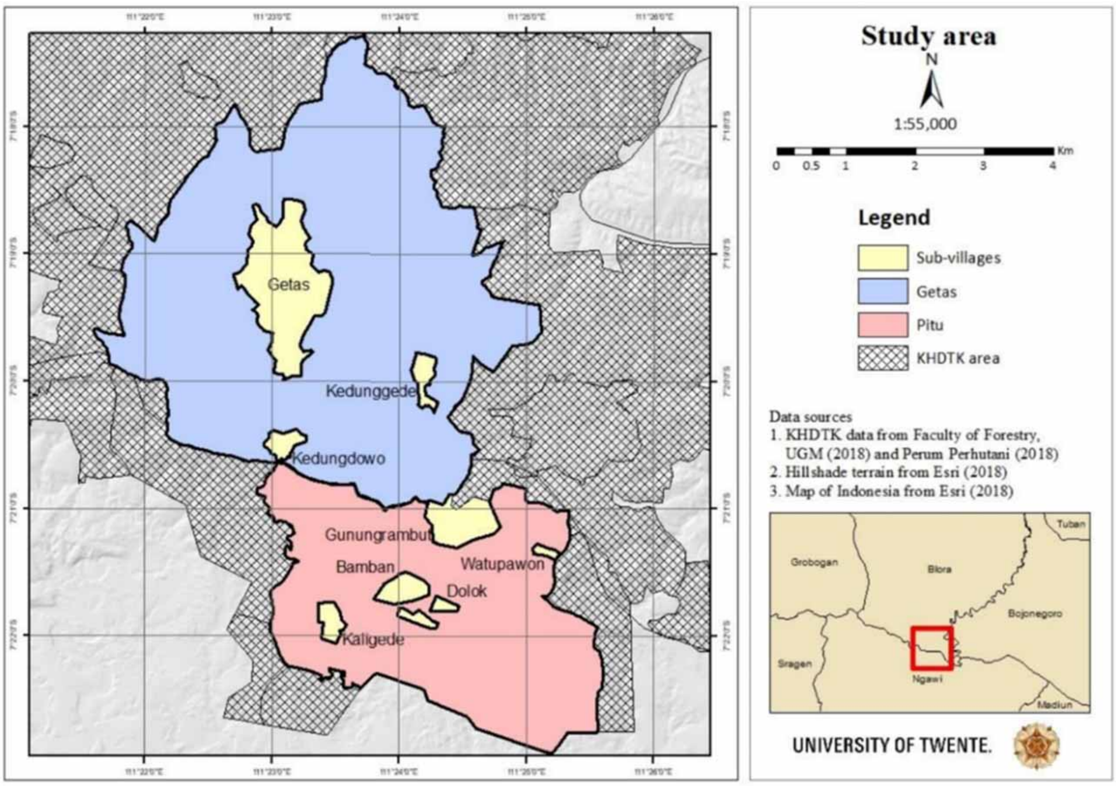

Figure 2 | Study area location.

Water Practice & Technology Vol 15 No 2
doi: 10.2166/wpt.2020.024

Table 1 | Districts and sizes of the study villages

Village	Sub-District	District	Province	Village area (ha)	Village proportion of total KHDTK area (%)
Getas	Kradenan	Blora	Central Java	2,265	21
Pitu	Pitu	Ngawi	East Java	1,214	11

According to the USDA (United States Department of Agriculture) classification, the KHDTK area is dominated by alfisol soil types (Yuwono *et al.* 2018), which contain aluminium and iron and are found mostly under forest stands. Alfisols are suitable for crop cultivation as they are generally fertile and productive because of high nutrient concentrations. Most of the UGM KHDTK area receives 2,000–2,400 mm/a of rainfall and it is in Schmidt-Fergusson's D (moderate) climate category (Yuwono *et al.* 2018). The Schmidt-Fergusson climate classification is based on the ratio of dry (<60 mm) to wet months (>100 mm), expressed as a percentage. Category D has a ratio of 60–100%. The rainy season lasts from November to March and the dry season from April to October.

The land cover map of the KHDTK area was made by spatial analysis of a recent aerial photograph. Figure 3 shows that there is much teak in both Getas and Pitu, although Pitu has a greater proportion. Thus, there is significant potential for agroforestry in the study area.

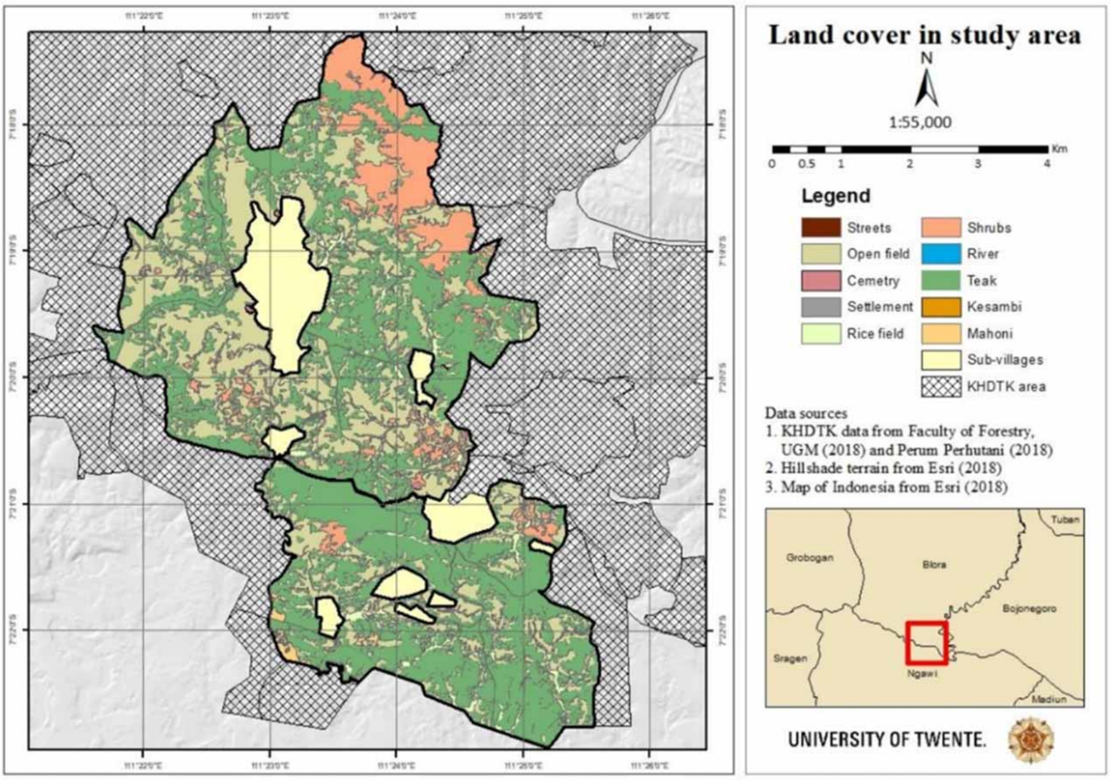

Figure 3 | Land cover in the study area.

MATERIALS AND METHODS

Q methodology (Q) was used to identify the variety of stakeholder viewpoints on the effects of different farming practices on water use. Q is a clearly structured, systematic and increasingly-used methodology designed to identify perception typologies (Zabala 2014). 17 statements – see Table 2 – were created on the basis of a literature review and ranked by 33 respondents during interviews

Water Practice & Technology Vol 15 No 2
doi: 10.2166/wpt.2020.024

Table 2 | Overview of the statements

No.	Statement
1	Water use in agroforestry systems is higher than that of monocropping systems
2	Monocropping systems demand more water than agroforestry systems
3	Increasing tree numbers improves water availability at regional scale
4	Tree roots take water in during the rainy season, and release it during the dry season
5	Trees consume water and compete with other water users – e.g. crops
6	Trees reduce surface water runoff from farmland
7	Are you interested in understanding how different farming practices affect water use on farmland?
8	Are you interested in understanding how agroforestry and monoculture systems affect farmland water use differently?
9	I believe that agroforestry and monocropping systems differ in their water use
10	In my opinion, all farming systems (agroforestry and monocropping) have similar water demands
11	In my opinion, agroforestry systems are a reliable tool for soil and water conservation on farmland
12	I believe agroforestry systems reduce flood risk
13	In this area, there are mostly monocropping rather than agroforestry systems
14	We try to encourage farmers to include trees on farmland
15	I prefer monocropping to agroforestry systems as trees use too much water
16	When applying agroforestry, I worry about the competition between trees and crops for soil water
17	I apply/We encourage farmers to apply agroforestry for soil and water conservation on farmland

or focus group discussions (FGDs) in a non-forced distribution along a five-level scale from fully agree (+2), via agree (+1), neutral (0), and disagree (−1), to fully disagree (−2). The key, water-related stakeholders in the study area are the village communities of Getas and Pitu, the local governments, the area's previous and current managers (Perhutani and UGM), and the watershed office (BPDASHL Solo).

Q Method in R software was then used to analyse these rankings, to help to construct the perceptions. Q Method reduced the full set of rankings to three distinct perceptions representing those with similar views. The number of perceptions to be extracted was determined through three criteria types; those selected must have an eigenvalue exceeding 1 (Saigal *et al.* 2005), the number of Q sorts determining each perception (Raadgever *et al.* 2008; Seyni *et al.* 2018), and the total amount of variability explained (Zabala *et al.* 2018).

RESULTS

The results consist of three components that lead to actual construction of the perceptions. Firstly, the extent to which a respondent represents a perception. The higher a respondent's loading on a perception, the more representative he is of that perception. Q Method then automatically assigns (i.e. flags) stakeholders to the perception with the highest loading. Secondly, the relation between statements and perceptions as indicated by z-scores; a weighted average of the scores given by the respondents that represent that perception. Thirdly, distinguishing and consensus statements, indicated by comparison of absolute differences between z-scores. The final step of Q consists of perception construction through the components described. Analysis of the first component leads to the findings as presented in Table 3. However, no loading is assigned to one of the respondents in the watershed office, since the loading was relatively high for all perceptions; thus, that column in Table 3 does not add up to 100%.

Water Practice & Technology Vol 15 No 2
doi: 10.2166/wpt.2020.024

Table 3 | Composition of stakeholders sharing a perception

Perception	Village community	Local Government	Perhutani	UGM	Watershed officer
A	–	44%	67%	25%	25%
B	Getas	56%	33%	50%	–
C	Pitu	–	–	25%	50%

The perceptions are roughly equally divided, with eight stakeholders representing the first perception, nine the second, and four the third. FGD respondents are considered a single stakeholder since they gave a unanimous ranking of the statements.

Analysis of the second and third components leads to a visualisation of the perception z-scores, ordered from the highest disagreement between perceptions (top) to the highest consensus (bottom) in Figure 4. It reveals the relatively high consensus between perceptions (10 statements of 17). A strong consensual attitude is observed on the desires to understand how different farming practices affect water use (statement 7), and how agroforestry and monocropping systems affect water use differently (8). Next is a consensus on some hydrologic benefits of agroforestry systems, such as increased regional water availability (3), and reduced risk of floods (12) and surface runoff (6). There is also general confidence that trees and crops do not compete for available soil water (16).

Beyond this consensus, three discourses were identified expressing distinct attitudes to the water use of farming practices. The first perception states strongly that monocropping systems use more water than agroforestry systems, while the second states the opposite (statements 1 and 2). The third perception comprises reluctance to assign the extent of water use to any specific system, but states that factors such as species and planting pattern define water use (1 and 2). The first and third perceptions are also confident that agroforestry systems are good for soil and water conservation, while the second reveals a more sceptical attitude (11 and 17). The first perception also focuses strongly on trees not competing with crops for soil water; while the third states that there

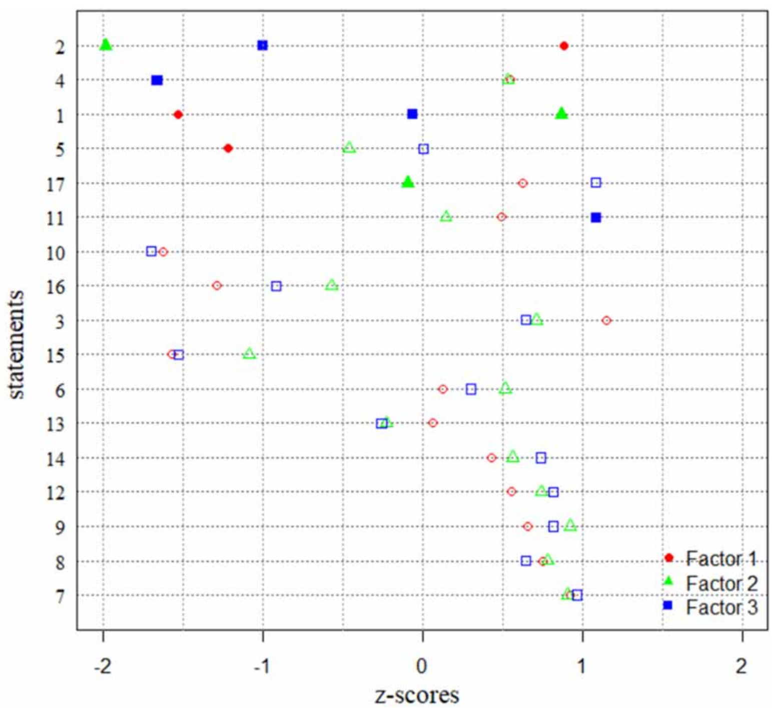

Figure 4 | Z-scores for the statements; the distinguishing perceptions are filled, indicating those with a significantly different z-score compared with the other perceptions. Factor 1 represents perception A, factor 2 perception B, and factor 3 perception C.

Water Practice & Technology Vol 15 No 2
doi: 10.2166/wpt.2020.024

could be competition, since agroforestry systems have a lower crop yield resulting in economic disadvantages (5). In contrast to the other two, the third perception strongly disagrees that tree roots soak up water in the rainy season and release it during the dry season (4).

DISCUSSION

There is a widespread belief in the community that forest reduction due to agricultural expansion is the main cause of an increasing number of disasters (e.g. floods and drought) because a larger proportion of rainfall becomes surface runoff rather than recharging groundwater (Bruijnzeel 1989, 2004; Ibánez *et al.* 2002; Ogden & Stallard 2013). As a result, agroforestry systems have become increasingly popular because of the perception that they may balance the maintenance needs and even increase productivity, while preserving ecological benefits (i.e. soil and water conservation). A cynical view of agroforestry also exists, however, due to competition for resources (e.g. water and nutrients) within such systems that might cause productivity to decrease (Ong *et al.* 2006). These contrasting perceptions of water-use in agroforestry are often based more on myths about forest and agriculture functions than on science. Unfortunately, they continue to dominate the views of policy makers and communities. They should be revised.

Divergent views were also found in this study. Communities from different villages have different perceptions on water use by agroforestry. Farmers from Getas focus on agroforestry systems with high water use, while Pitu farmers think that this does not matter as all systems are rain dependent. There are also different views in the local governments and Perhutani as to whether monocropping or agroforestry systems have higher water use. All three perceptions are found in the watershed office and UGM. Yet, the watershed office is generally confident in interpreting the benefits of agroforestry systems, which it regards as a solution offering benefits to all, because the land is conserved while farmers keep their livelihoods. Despite the diverging views in UGM, there is also a shared belief that successful management of agroforestry leads to more sustainable forest in the study area. The contrast in public perceptions of the roles of agroforestry and monocropping in relation to water remains large, probably due lack of research providing clear understanding of the issues.

Q brings a level of abstraction to perception identification, enabling identification to be very systematic and ordered. Q can be used with a small, select sample because it does not generalize the results to a larger population. This study consisted of 33 respondents; in conservation contexts they range typically from 26 to 46 (Zabala *et al.* 2018). Consequently, the results represent the population of perceptions rather than that of stakeholders (Cuppen *et al.* 2016). Insights are gained, therefore, into the variety of perceptions within and between stakeholder groups (Table 3), although the exact distribution is not known.

CONCLUSIONS

Q methodology, as employed in this study, has helped to identify consensus amongst stakeholders and three distinct perceptions. The key stakeholders related to the water issues in the study area are the village communities of Getas and Pitu, the local governments, the previous and current managers of the area, and the watershed office. There is consensus among them on some hydrological benefits of agroforestry systems, such as increased regional water availability, and reduced flood and surface runoff risk. There is also general confidence that trees and crops do not compete for soil water. Beyond this, three perceptions express distinct attitudes regarding the water use of farming practices. The first states strongly that monocropping systems use more water than agroforestry, while the second states the opposite. Those holding the third perception are reluctant to assign the extent of

Water Practice & Technology Vol 15 No 2
doi: 10.2166/wpt.2020.024

water use to a specific system, and state that factors such as species and planting pattern define water use. The first and third perceptions are based on confidence that agroforestry systems are good for soil and water conservation, while the second is based on more sceptical attitudes. Each stakeholder group represents two or even all three perceptions. Thus, within and between stakeholder groups there are contradicting beliefs of the effects of agroforestry and monocropping systems on water use.

As for management of the area, it is impossible to address the stakeholder groups in one specific manner, as each group represents several perceptions. Within stakeholder groups there are different knowledge levels, and stakeholders believe in contradictory benefits or disadvantages from farming practices. Therefore, careful identification of those beliefs that are true versus those based on myth is important.

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