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RESEARCH PAPER

Transmission of swidden farming ritual knowledge among households in eastern Madagascar

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Abstract This project evaluates the influence of relationship types (i.e., kinship and friendship) on swidden farming ritual knowledge variation in eastern Madagascar. This is an extension of prior research that found that the only statistically significant explanation of variation in swidden farming ritual knowledge was the community in which an individual lived. In part due to farmers reporting that they learned rituals from their parents with little or no influence from other relationships, this project formally evaluates kinship and other relationships to discover the pattern of within group sharing of cultural knowledge. The results presented suggest that the method of knowledge transmission may be one of the primary causes for the current failure of agricultural development programs in Madagascar.

Keywords Madagascar · Swidden farming · Cultural models · Social network analyses

Introduction

This research evaluates the influence of kinship and other relationships on swidden (slash-and-burn) farming ritual knowledge variation in eastern Madagascar. Prior research found that variation in swidden farming ritual knowledge is not correlated with age, gender, ethnicity, religious, or affiliation with conservation programs (Hume 2012). The only explanation of variation found to be statistically significant was the community type in which an individual lived (city, village, and extended family residences). While statistically significant, community location explained only a small proportion of the total variation. Anecdotal evidence from group interviews during previous research suggests that swidden farming ritual knowledge variation is correlated with kinship; farmers learn rituals from their parents with little or no influence from other peer relationships. Based upon this importance of kinship in farming knowledge, the following hypothesis was tested in a community of approximately 150 adults in Mahatsara village in the mountain rainforest of eastern Madagascar: H_1: as agreement of swidden farming rituals increases, kinship relatedness increases.

This research as well as prior research (Hume 2005, 2006, 2009a, b, 2012) is a collaborative effort by the author and several agencies,[1] to determine the link

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[1] The following is the full list of collaborators in this research: Institut de Civilisations/Musée d'Art et d'Archéologie de l'Université d'Antananarivo; Centre d'Études et de Recherches Ethnologiques et Linguistiques, Université de Toamasina; Ministre de la Recherch Scientific, Direction Inter Regionale Centre, Regional de Recherch Est, FOFIFA, Toamasina; Ministre des Eaux et Forêts, Toamasina; Ecole d'Application des Sciences et Techniques Agricole, Analamalotra, Toamasina; Commissaire General Charge des Relations Publiques

between culture and agricultural change in eastern Madagascar. Each of the agencies seek to replace swidden farming with irrigated rice agriculture due to the negative impact of swidden agriculture on local and global biodiversity, lack of sustainability, and low crop yields. The agencies have primarily been concerned with economic and technological development, ignoring local culture. Due to the lack of funding and understanding of how cultural knowledge is transmitted, efforts to end swidden farming in eastern Madagascar have been largely unsuccessful. Small-scale attempts in training community master farmers and providing sporadic agricultural technician aid has not resulted in long-term change. Prior research found that the rural Malagasy farmers do not learn new agricultural techniques from their peers, or master farmers who are trained by various governmental and non-governmental agencies (Hume 2005: 93–94). This research shows how agricultural knowledge is transferred primarily through household relationships and not exclusively through kinship relations, and that there is little peer to peer transfer of knowledge outside of households. These results have implication for development programs to design information dissemination campaigns efficiently and effectively in Madagascar and elsewhere.

Conservation in Madagascar

Madagascar is a biodiversity hotspot, which makes it an area of international environmental conservation concern due to its high diversity of endemic flora and faunal species (Myers et al. 2000: 857). Madagascar's current biodiversity is considered under threat as only 10% of primary growth vegetation is remaining (Du Puy et al. 1996; Myers et al. 2000: 857; Nelson and Horning 1993). It is further estimated that approximately 1.5% of primary growth vegetation is converted to subsistence farming and grazing each year (Green and Sussman 1990). The current estimates of endemism of flora and fauna in Madagascar vary from between 75 and 85% (Dransfield and Beentje 1995; Glaw and Vences 1994; Mittermeier et al. 1995). It is argued that since Madagascar holds 3.2% of the global floral and 2.8% of the global vertebrate species, any biodiversity loss in Madagascar drastically affects global biodiversity (Myers et al. 2000:857). One effort among conservation biologists and the Malagasy government is to determine which areas of Madagascar should be protected to maximize biodiversity conservation (Kremen et al. 1998). Extinction events in Madagascar influence not only the local biodiversity but have global ramifications as well.

Swidden farming in areas with high endemism of endangered or threatened species is of interest to multiple agencies within Madagascar. The Ministre de l'Agriculture et de l'Elevage (Ministry of Agriculture and Livestock) is concerned with the destruction of forests that may take as long as 50 years to regrow to secondary forests (Hume 2006: 292–293). The Ministre des Eaux et Forêts (Ministry of Water and Forests) is also concerned with the continued reduction of forested areas in Madagascar that result in biodiversity loss (Hume 2006: 294–295). The local L'Association Nationale pour la Gestion des Aires Protégées (National Association for the Management of Protected Areas) office that manages Andasibe-Mantadia National Park, considers farming along the park edges as one of the greatest threats to both the parks and the species they contain. Each of these and other agencies see agricultural change as one of the most important way to preserve the biodiversity of Madagascar.

Agricultural change in Madagascar

Attempts to replace swidden farming with irrigated rice agriculture in eastern Madagascar have largely failed. The government and non-governmental organizations (NGOs) explain the barrier to success as being due to lack of funding and the unwillingness of indigenous Malagasy farmers to change (Hume 2006). The limited success in agricultural development is far more complicated. Because of population increases and limited fertile farmland, fallow periods are decreasing to less than 3 years, the fertility of the soil is decreasing, and topsoil is eroding into the ocean. In response, the Malagasy government has collaborated with international aid and development organizations (e.g., the United States Agency for International

Footnote 1 continued
et du Developpement Socio-Cultural; Ministre de l'Agriculture et de l'Elevage, Direction Inter Regionale du Developpement Rural Toamasina; and L'Association Nationale pour la Gestion des Aires Protégées, Toamasina and Parc National D'Andasibe.

Development and International Rice Research Institute) to increase crop yields and reduce the human impact on environmentally protected areas (e.g., Anonymous 2008). The Malagasy government is developing technological solutions without consideration for the belief systems of localized rural farmers. Swidden farming is more than a technique, as it incorporates religious symbolic content (Hume 2005: 73–77; Razafiarivony 1995) and constitutes part of farmers' sense of identity (Harper 2002: 24; Hume 2006: 299–301). Any agricultural development project must not only balance economic costs and benefits, but also consider the political, ecological, and cultural consequences of change.

Malagasy swidden rice farming (*tavy*) incorporates both prayers and offerings to indigenous spiritual beings at several stages of the farming process regardless of the practitioner's religious affiliation (i.e., Christianity and Islam). These ritual acts occur before vegetation is cut to create a new field, before vegetation is burned, before rice seeds are planted, before rice is harvested and before the rice is brought into the house. Prayers are offered during each of these rituals and may be directed to *Andriamanitra* (God), *razana* (the ancestors whose spirits occupy the landscape), or *zanahary* (spirits who live on the land). In addition to prayers, objects may be offered and include *vary fotsy* (cooked white rice) to create a pact between the farmer and spirit, *masomboly* (seed reserved to be sown) symbolizing fertility, *tantely* (raw honey) symbolizing health, and either *toaka-Gasy* (distilled rum made with sugar cane) or *betsabetsa* (fermented beer from rice and honey) to secure the favor of spiritual beings (see Hume 2012 for a full explanation of *tavy* rituals). These rituals are deeply shared within a religious worldview of how humans should interact with the spiritual world and help formulate a Malagasy swidden rice farmers identity.

Agreement and knowledge variation

This research is related to work by other anthropologists in two broad areas: variation of cultural models and indigenous conservation. The interest in cultural modeling and quantitative analysis of inter-cultural variation can be traced to early cognitive anthropology (D'Andrade 1995: 11–13) through more recent work on theories of knowledge (Bennardo and de Munk 2014; Bloch 2012) but has also been adopted by several sub-disciplines of cultural anthropology concerned with cultural variation. For example, the methods developed in cognitive anthropology on cultural knowledge are now being used in applied development research (e.g., Sillitoe, Dixon, and Barr 2005). In environmental anthropology, the focus of research has moved from interest in beliefs or behavior (e.g., Alvard et al. 1995; Alvard and Kunzar 2001; Ruttan and Borgerhoff Mulder 1999; Winterhalder and Lu 1997) to understanding inter-cultural variation of cultural knowledge of the environment and what effect that knowledge has on behavior (Nazarea 1999: 93–4). Although the causal links between knowledge and behavior are still tenuous. While there is much interest in cultural models in environmental anthropology, few have included an analysis of the inter-cultural variation of the models (e.g., Schareika 2001).

In the analysis of inter-cultural variation, there is disagreement in whether it is the similarities, differences, or both similarities and differences between individuals which constitute shared cultural knowledge. In consensus theory, the analysis of inter-cultural variation allows for the measurement of the degree to which cultural models are shared (Boster 1985, 1987; Brewer et al. 1991; Garro 1988, 2000; Romney 1989, 1999; Romney et al. 1986, 1987; Strauss and Quinn 1998). Most of the works cited above statistically measure consensus using similarity matrices and employing diverse types of factor analyses. For example, principal components analysis (PCA), a type of factor analysis, has been demonstrated as an effective method for examining similarity matrices of cultural variation not only within, but also between cultural groups (Handwerker 2002). To measure both the differences and similarity matrices of cultural variation, the quadratic assignment problem (QAP) and social network analysis (SNA) have been employed (Boster 1986; Krackhardt 1987).

In Madagascar, the majority of the environmental anthropology research has been concerned with political ecology (e.g., Gezon 1997, 1999a, b), land use (e.g., Durbin and Ralambo 1994) and ethnobotany (e.g., Byg and Balslev 2001; Novy 1997). So far, only the author's own work (Hume 2005, 2006, 2012) explicitly measures how indigenous knowledge variation is connected with environmental problems in Madagascar. Only through a variety of viewpoints within anthropology (e.g., political ecology and

cognitive anthropology) and between disciplines (e.g., economic botany and cultural anthropology) can there be hope in finding a solution to Madagascar's environmental crisis (Kaufmann 2006). The results of the research presented will add both to the current understandings of cultural models of conservation in non-western contexts and to the understanding of current natural resource use in Madagascar.

Prior research on cultural models of swidden farming in Madagascar

Qualitative analyses of ethnographic interviews during fieldwork conducted in 2003 (Hume 2005) suggested that swidden farming rituals inversely vary in proportion to the number of agricultural development programs within the community. Those farmers with more connections with development programs reported participation in fewer farming rituals. Due to this, the following hypotheses was designed to be tested: as knowledge of non-indigenous conservation practices increases, knowledge of swidden farming rituals decreases (Hume 2005). Thirty interviews were conducted with farmers in Toamasina and Andasibe where the shared ritual behavior data during swidden farming of rice were collected. The qualitative data were then used to construct a cultural model of swidden farming rituals.

In the summer of 2004, a questionnaire built of five ritual schemas of a proposed cultural model of swidden rice farming rituals was used to collect data from 185 farmers in the Andasibe region, of eastern Madagascar (Hume 2012). The communities studied are in the mid-level highlands of the rainforest. Interviews were conducted within three communities that had differing levels of agricultural development program involvement: (1) Andasibe—an ethnically diverse town with an estimated population of 5000 with seven programs, (2) Mahatsara—a village with an estimated population of 150 with three programs, and (3) Ampangalatsary—approximately 4 km south of Andasibe with many small-interspersed communities and an estimated population of 1000 with one program (Hume 2012).

The cultural model of swidden farming consists of the following three components: five ritual schemas (cutting, burning, planting, harvesting, and bring rice into the house); distinct ritual events each with five possible offerings (*vary fotsy*, *masomboly*, *tantely*, *toaka-Gasy*, and *betsabetsa*); and entities (*Andriamanitra*, *razana*, and *zanahary*) to which the farmer may pray. Principal component analysis (PCA) was used to analyze informant agreement and general linear models (GLM) for the analysis of variation between the model and demographic variables (in part after Romney et al. 1986). Although Romney et al. (1986) used minimal residual factor analysis, PCA was used because it has equivalent results and tends not to overestimate agreement. The results of the analysis on the entire sample, ethnic Betsimisaraka (the local ethnic majority), and each sample area are shown in Table 1. The factor plots (first against second factor scores of informants) revealed patterns of variation among informants on two variables: (1) community and (2) percentage of total rituals (see Fig. 1). There are tighter groupings (less intra-cultural variation) within the Mahatsara and Ampangalatsary samples than within the Andasibe sample. Both a t-test and GLM analysis show that community is related to the second factor ($t - 13.210$, $f\ 48.282$, $p < 0.001$) (Hume 2012). In addition to community, the percentage of total rituals by each informant corresponds to the second factor ($t - 23.187$, $f\ 35.393$, $p < 0.001$) (Hume 2012). The community and number of rituals reported done both are important variables in explaining the variation within and between communities.

Table 1 Intercultural variation-principal components analysis I (Hume 2012)

Sample Group	N	Variance explained by 1st factor (%)	Ratio between the 1st and 2nd eigenvalues
All	185	40.18	3.3:1
Betsimisaraka	149	40.05	3.4:1
Betsimisaraka in Andasibe	50	49.44	3.4:1
Betsimisaraka in Mahatsara	49	42.41	3.8:1
Betsimisaraka in Ampangalatsary	50	47.08	4.3:1

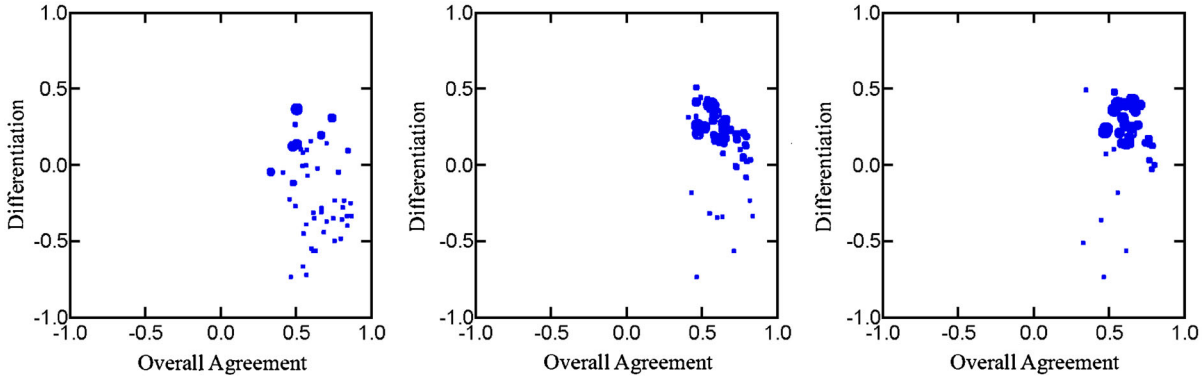

Fig. 1 Scatter plots of the first factor (overall agreement) and second factor (differentiation) resulting from the principal components analysis of each sample (Andasibe left, Mahatsara center and Ampangalatsary right). The size of each informant point represents the percentage of total rituals performed (30–80%, larger points represent larger percentages). (Hume 2012)

Further analysis using a Pearson's correlation or the percentage of swidden farming rituals known and the number of conservation organizations in the area (Andasibe 7, Mahatsara 3 and Ampangalatsary 1) shows a negative correlation ($r - 0.585$, $p < 0.001$) (Hume 2012). The numbers used (Andasibe 7, Mahatsara 3 and Ampangalatsary 1) may represent other phenomena than swidden farming ritual knowledge (e.g., the degree of urbanity, social control, and/or population density). In addition, an ANOVA between the amount of ritual performed and the location of the informant found a significant difference between the three communities (F 22.41, $P > 0.001$, see Fig. 2) (Hume 2012). Data were not collected in collaboration with the conservation organizations, so the hypothesis that conservation organizations influence ritual agricultural knowledge, though supported by quantification, was not accepted. A valid measure of the effects of conservation organizations would require collection and correlation of each program's involvement with each community.

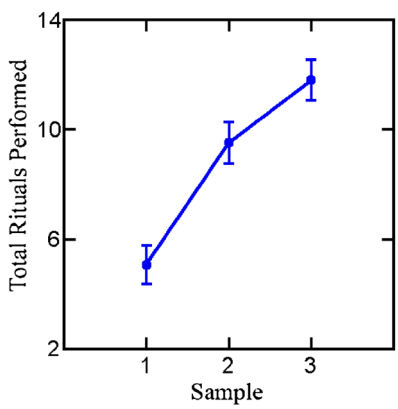

Fig. 2 Least squares means plot from ANOVA between total rituals performed and sample populations (Andasibe 1, Mahatsara 2 and Ampangalatsary 3). (Hume 2012)

Methods in new research

For the research project reported in this work, I collected data directly from informants in Mahatsara, Madagascar. Mahatsara was chosen for this research due to its relatively small size (approximately 150 adults within a 12 acre village), homogeneity (most inhabitants are from the local Betsimisaraka ethnicity), and importance to conservation groups given it proximity to the Andasibe-Mantadia National Park. Data were collected with the aid of a research assistant from Andasibe (the largest local town) and another from Mahatsara over a period of 1 month at Mahatsara village. Each interview consisted of four topical parts: (1) kinship relationships, (2) peer relationships, (3) demographic information, and (4) swidden farming ritual practices (using the same instrument as prior research, see Hume 2012). First, each informant was asked to name and describe the relationship to any kin living in Mahatsara as well as those who lived in the same household. Second, each informant was asked to name and describe the relationship to any peer relationship (e.g., friendship, workplace, farming, and religion) to anyone living in Mahatsara. Third, general demographic information (e.g., age, ethnicity,

religion, years lived in the area, years farming, items grown, other supplementary occupations, and irrigated agriculture experience) was collected. Finally, the survey instrument created during previous research was used to collect data on swidden farming ritual practices.

The relationships between kinship, peer relationships, and demographics to swidden farming ritual practices were analyzed in two ways: relationships based upon similarities (consensus analysis), and relationships based upon both similarities and differences (social network analysis). The results from each type (consensus and social network analyses) were used to test the hypothesis: as agreement of swidden farming rituals increases, kinship relatedness increases. The swidden farming ritual practices data were first analyzed using factor analysis of the inter-informant agreement matrix and the results were used to explore the pattern of intra-cultural variation in the cultural model of swidden farming ritual practices (Boster 1981, 1984; Romney 1999; Romney et al. 1986).

Factor analysis provides a way to test whether the variation is around a single cultural model (Handwerker 2002: 111–112). In addition, this method allows one to determine the culturally 'correct' answer without the researcher's prior knowledge (Romney et al. 1987). One can infer that informants have converged on a single cultural model if the first eigenvalue is several times larger than the second and if the first factor scores are all positive (Romney et al. 1986: 323). In addition, Pearson's R statistics of the eigenvalues against demographic information (age, sex, etc.) was used to explore if differences between swidden farming ritual practices of different community members were significantly different due to demographics. Social network analysis (SNA) was then used to examine the relationships between kinship relationships, peer relationships, demographic information, and swidden farming ritual practices. Data was analyzed using UCINET (Borgatti 2008), a computer program that statistically determines the relationship between members of a social network and visualized using NetDraw (Borgatti 2002).

Findings

The questionnaire of ritual offerings and entities prayed to for the five ritual schemas was completed by 48 informants within Mahatsara during the summer of 2011. Local records indicated that there were approximately 70 adult residents of Mahatsara at the time research was conducted, but several members were absent because they were at secondary residences or traveling to other areas of the county. Of the 48 informants, 68.75% were male and 31.35% were female. Ages ranged from 19 to 80 years of age with a 39.51 average. Informants in this sample represent 20 of the approximately 30 households (defined by locals as residences where people eat and sleep together) within Mahatsara.

Principal components analysis (PCA) and Chronbach's α were used to analysis intercultural variation with the questionnaire data. Both PCA and Chronbach's α are statistical tests for whether variables (in this case ritual elements) are correlated with each other forming sets of correlated variables. PCA is a more rigorous test, but cannot be used on small samples, while Chronbach's α may be used with small sample sizes. The PCA of the entire questionnaire of ritual elements yielded 47% of the variance explained by the first factor and a 3.4:1 ratio between the first and second factors and a Chronbach's α of 0.916 (see Table 2). The entire ritual set does not meet the minimum standards for a consensus model of at least

Table 2 Intercultural variation - principal components analysis II

Ritual Components	N	Variance explained by 1st factor	Ratio between the 1st and 2nd factors
Entire Ritual Set (Cronbach's α 0.916)	48	47%	3.4:1
Basic Set (Cronbach's α 0.881)	24	58%	3.8:1
Planting Set (Cronbach's α 0.900)	9	–	–
Preparation Set (Cronbach's α 0.872)	8	–	–
Praying Set (Cronbach's α 0.953)	4	–	–
All (Cronbach's α 1.000)	3	–	–

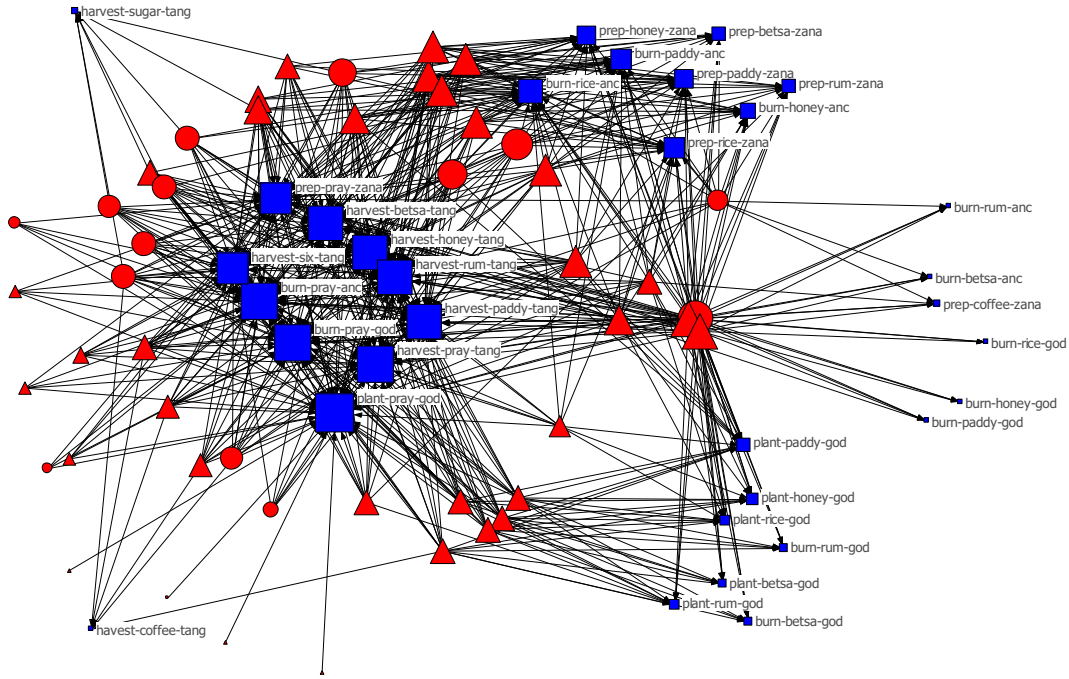

Fig. 3 Network diagram of informants (red nodes: triangles are males and circles are females) by ritual elements (square blue nodes). Size of each node is determined by eigenvector centrality (number of ties to other nodes proportional to the number of ties to its connected nodes). The diagram is structured by layout with node repulsion and equal edge length bias (color figure online)

50% and 3:1 (Bernard 2011: 553) but does meet the minimum standards for questionnaire reliability of at least 0.80 (Bernard 2011: 249. It appears that there is a set of shared cultural knowledge as shown by the Chronbach's α, but that there is not consensus about what exact set of ritual elements are the norm for the entire community, as shown by the PCA analysis.

The two-mode network analysis (informants by ritual elements) yielded a diagram where ritual elements were grouped (see Fig. 3). These groupings show that different informants have different sets of ritual elements that they perform. For example, there is what may be identified as the most common "basic set" of ritual elements (i.e., preparation ritual [pray to *Zanahary*], burning ritual [praying to god and the ancestors], planting ritual [praying to god], and harvest ritual [praying with the *Tangalamena* (keeper of customs) and giving *betsabetsa*, honey, paddy, and rice]) are practiced by all informants.

The principle components analysis (PCA) of the basic set of ritual elements with the informants that only practiced these elements yielded 58% of the variance explained by the first factor, a 3.8:1 ratio between the first and second eigenvalues (factors) and a Chronbach's α of 0.881 (see Table 2). The basic ritual set does meet the minimum standards for a consensus model and for questionnaire reliability. While every informant practices the basic ritual set, half of the 48 informants exclusively practice the basic ritual elements where the other 24 informants also practice other groupings (sets) of ritual elements. Three informants reported that they practice all the ritual elements (Chronbach's α 1.000), which may be due to these informants feeling that they must agree with each part of the questionnaire (see Appendix).

The planting ritual set is practiced by nine informants who also practice the basic ritual set. The planting ritual include offering paddy, honey, rice, rum, and betsabetsa to god before planting and both rum and betsabetsa to god before burning. Due to the small number of informants that practice the planting ritual set, a PCA could not be run. However, the Chronbach's α was 0.900 (see Table 2). The basic ritual set does meet the minimum standards for questionnaire reliability.

The preparation ritual set is practiced by eight informants who also practice the basic ritual set. The preparation ritual set includes offering honey, rum,

betsabetsa, and rice to the *Zanahary* (spirit) before cutting/preparing field and paddy, rice, and honey to the ancestors before burning the fields. Due to the small number of informants that practice the planting ritual set, a PCA could not be run. However, the Chronbach's α was 0.872 (see Table 2). The basic ritual set does meet the minimum standards for questionnaire reliability.

The praying ritual set is practiced by four informants who also practice the basic ritual set. The praying ritual set includes offering rice, honey, and paddy to god before burning; offering *betsabetsa* to the ancestors before burning; praying to god and the ancestors before burning; and offering coffee to the *Zanahary* before cutting/preparing field. Due to the small number of informants that practice the planting ritual set, a PCA could not be run. However, the Chronbach's α was 0.953 (see Table 2). The basic ritual set does meet the minimum standards for questionnaire reliability.

Prior research suggested that kinship and friendships may explain similarities among informant ritual practices. Data collected on kinship relations, friendships, and households was entered as one-mode network data and each informant was given an attribute by which ritual set they belong (basic, planting, preparation, praying, and all). This data was then visualized using Netdraw (see Figs. 4 through 7). Close affinal (kin related by marriage, such as husbands, wives, parents-in-law, children-in-law, etc.) and consanguineal (kin related by blood, such as children, parents, grand-parents, and grand-children) kin show only minimal patterns of ritual practice set sharing where individuals with shared ritual sets are often connected but also dispersed throughout the sample (see Fig. 4). Results of interviews from prior fieldwork suggested that families share common ritual practices due to parents teaching children what rituals should be performed. However, the data (shown in Fig. 4) do not support transference of cultural data through kinship alone.

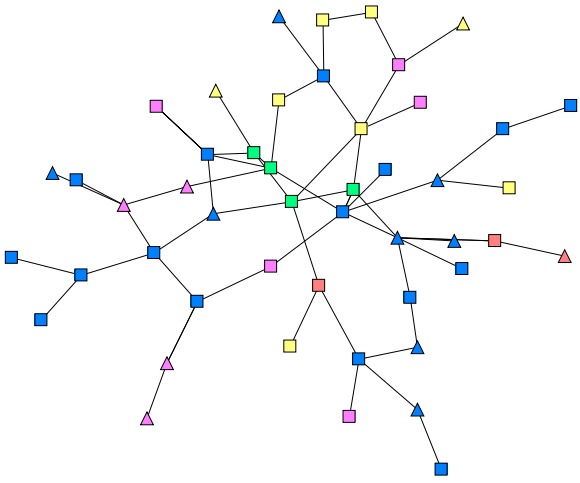

Fig. 4 Close kin network diagram of informants (triangles are males and squares are females) where color indicates ritual practice set (basic blue, planting purple, preparation yellow, praying green, and all red). The diagram is structured by layout with node repulsion and equal edge length bias (color figure online)

In addition to kin relationships, there was evidence that friendships may play a role in how swidden farming rituals are shared within the community. Friendship (informants that reported each other as fiends) shows only minimal patterns of ritual practice set sharing, as individuals may be connected to others that practice the same ritual set but are also connected with those that do not(see Fig. 5). Diagramming both friend and kin relationships (first and second degree affinal and consanguineal kin) still only show minimal patterns of ritual practice set sharing (see Fig. 6). The notion that kinship, friendship, or some combination of both would explain the variation in swidden farming ritual practices is not supported by the data that were collected (Fig. 7).

The final relationship type data that was collected was household. A household relationship is defined by this community as individuals that both eat and sleep in the same physical structure. Generally, the household only includes close kin (i.e., grand-parents, parents, children, and spouses), but these kin may have a larger relational distance to each other (most often cousins, aunts, and uncles). When the household data is visualized by ritual practice set, there is a strong pattern of sharing, with only one informant not sharing the same ritual set as her household. She practices the basic ritual set as well as the planting set, while the rest of her household only practices the basic set. It is unknown if this is a new member of the household or from where she may acquire this practice and what has prevented the rest of the household from sharing that ritual practice.

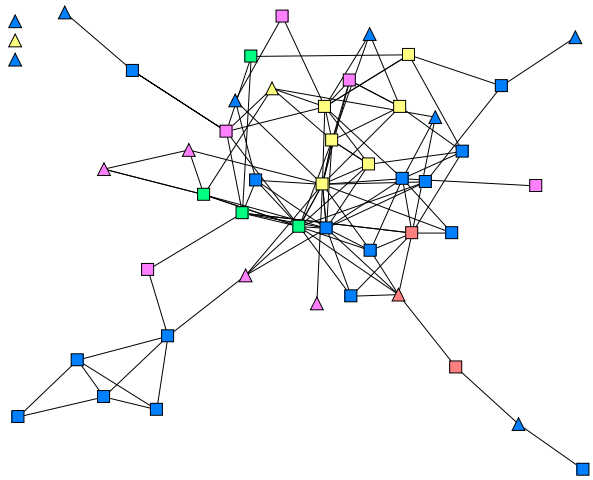

Fig. 5 Friendship network diagram of informants (triangles are males and squares are females) where color indicates ritual practice set (basic blue, planting purple, preparation yellow, praying green, and all red). The diagram is structured by layout with node repulsion and equal edge length bias (color figure online)

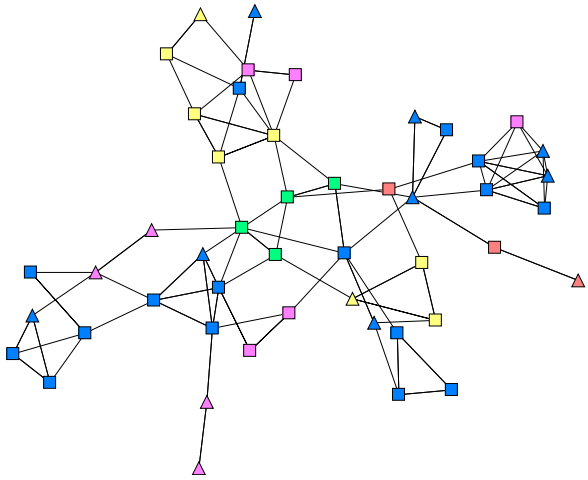

Fig. 6 Friendship and kin (first and second degree affinal and consanguineal kin) network diagram of informants (triangles are males and squares are females) where color indicates ritual practice set (basic blue, planting purple, preparation yellow, praying green, and all red). The diagram is structured by layout with node repulsion and equal edge length bias (color figure online)

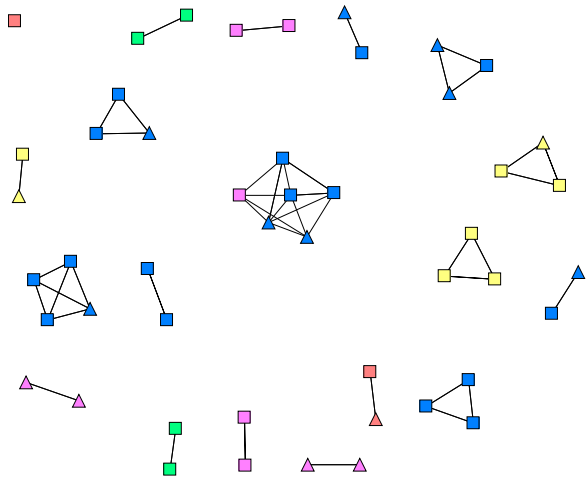

Fig. 7 Household (people who eat together and sleep in the same structure) network diagram of informants (triangles are males and squares are females) where color indicates ritual practice set (basic blue, planting purple, preparation yellow, praying green, and all red). The diagram is structured by layout with node repulsion and equal edge length bias (color figure online)

Discussion and conclusion

The finding that household membership better explains swidden farming rituals than kinship and friendship relationships alone is not surprising. It was assumed that kinship had a primary role in ritual practices due to group and individual interviews in prior field seasons. In one particular group interview with five young male informants, they explained their differing use of ritual practices by saying that they learned their ritual practices from their fathers and that they continued those traditions, even when their crop yields were lower than other famers who practiced different rituals. Several informants in individual interviews explained that they do not speak with other farmers about rituals or other non-ritualistic farming techniques. This and other data suggested that kinship was most important in the sharing of ritual practices.

Household, on the other hand, also played an explanatory role in earlier interviews, but not as an explanation of ritual practice sharing. Put simply, whenever there is a work activity on the field that requires much labor (cutting, burning, planting, and harvesting), the entire household takes part. A farmer only works in the field alone when weeding and protecting the crop from pests. Informants, though, never explained that they worked with their household, but reported that their family helped, which on reflection was a proxy for household in their explanation. The group labor activities all include ritual practices, prayers and offerings made before cutting, burning, planting, and harvesting.

As with other environmental anthropology work on the relationships between knowledge and behavior, this research also struggles with identifying the causal links between the two. It is not known how pliable individual's cultural models of swidden rituals may be and to what extent they may result in specific behaviors. For example, when someone joins a new household in marriage, does their cultural model adapt to that of the new household or do they only join households that share the same culture model as their previous household? To answer this question would require a larger sample of households over a significant period to track how cultural models are shared and change with household movement and other changes within the community.

The relevance of the results of the project to anthropology is twofold. First, by using the methods previously developed within cognitive anthropology to understand the relationships between agricultural knowledge and kinship relatedness, the project continues the historical concern of anthropology on the mechanisms through which cultural knowledge is transmitted. Second, this project used two different methods of determining the inter-cultural variation of swidden farming knowledge: (1) relationships based upon similarities (consensus analysis), and (2) relationships based upon both similarities and differences (social network). The multi-method testing provided evidence for determining the validity of each method. Finally, the obtained results add to the current scholarship on models of indigenous conservation and how these models are connected with behavior, which may also be applied to the current agricultural development problems in Madagascar.

The results of this project have been made available to Malagasy government and non-governmental agencies and organizations in constructing agricultural development programs implementing the transition from swidden farming to irrigated rice agriculture. Prior attempts to disseminate agricultural knowledge (e.g., master farmer programs and on-site agricultural technician workshops) in Madagascar have largely failed. Development programs would benefit from taking advantage of this pre-existing indigenous mechanisms of knowledge transmission. While the use of households as a transmitter of agricultural knowledge requires long-term participation of household members, the mechanism of cultural transmission already exists. In sum, the results of this research address not only problems of theory, method, and knowledge modeling in anthropology, but also critically important solutions to problem of agricultural development in a nation that is currently in an environmental crisis.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Appendix

Scale (Hume 2005 and 2012)

Code	Malagasy	English
1	*Mifanaraka araky izany mihitsy*	Completely agree
2	*Mifanaraka eo eo ihany*	Somewhat agree
3	*Tsy mifanaraka eo eo ihany*	Somewhat disagree
4	*Tsy mifanaraka araky izany mihitsy*	Completely disagree

Swidden Farming Ritual Questionnaire (Hume 2005, 2012)

No.	Malagasy	English
1	*Misy fangatahana amin'ny zanahary atao rehefa anao tavy?*	Should you pray to the *zanahary* before preparing a place to do *tavy*?
2	*Misy vary fotsy apetraka ve rehefa hikarakara tavy?*	Should you offer paddy to the *zanahary* before preparing a place to do *tavy*?
3	*Misy masom-boly apetraka ve rehefa hikarakara tavy?*	Should you offer rice to the *zanahary* before preparing a place to do *tavy*?
4	*Misy tantely apetraka ve rehefa hikarakara tavy?*	Should you offer honey to the *zanahary* before preparing a place to do *tavy*?
5	*Misy toaka-Gasy apetraka ve rehefa hikarakara tavy?*	Should you offer rum to the *zanahary* before preparing a place to do *tavy*?
6	*Misy betsabetsa apetraka ve rehefa hikarakara tavy?*	Should you offer *betsabetsa* to the *zanahary* before preparing a place to do *tavy*?
7	*Mikiaka zanahary ve rehefa andaro tavy?*	Should you pray to *andriamanitra* before burning?
8	*Mametraka vary fotsy amin'ny zanahary ve rehefa andoro?*	Should you offer paddy to *andriamanitra* before burning?
9	*Mametraka masom-boly amin'ny zanahary ve rehefa andoro?*	Should you offer rice to *andriamanitra* before burning?
10	*Mametraka tantely amin'ny zanahary ve rehefa andoro?*	Should you offer honey to *andriamanitra* before burning?
11	*Mametraka toaka-Gasy amin'ny zanahary ve rehefa andoro?*	Should you offer rum to *andriamanitra* before burning?
12	*Mametraka betsabetsa amin'ny zanahary ve rehefa andoro?*	Should you offer *betsabetsa* to *andriamanitra* before burning?
13	*Mila mivavaka amin'ny razana ve rehefa amboly?*	Should you pray to the ancestors before planting?
14	*Mametraka vary fotsy amin'ny razana ve alohan'ny amboly?*	Should you offer paddy to the ancestors before planting?
15	*Mametraka masom-boly amin'ny razana ve alohan'ny amboly?*	Should you offer rice to the ancestors before planting?
16	*Mametraka tantely amin'ny razana ve alohan'ny amboly?*	Should you offer honey to the ancestors before planting?
17	*Mametraka toaka-Gasy amin'ny razana ve alohan'ny amboly?*	Should you offer rum to the ancestors before planting?
18	*Mametraka betsabetsa amin'ny razana ve alohan'ny amboly?*	Should you offer *betsabetsa* to the ancestors before planting?
19	*Mivavaka amin'ny andriamanitra ve ianareo alohan'ny amboly?*	Should you pray to *andriamanitra* before planting?
20	*Mametraka vary fotsy amin'ny andriamanitra ve ianareo alohan'ny amboly?*	Should you offer paddy to *andriamanitra* before planting?
21	*Mametraka masom-boly amin'ny andriamanitra ve ianareo alohan'ny amboly?*	Should you offer rice to *andriamanitra* before planting?
22	*Mametraka tantely amin'ny andriamanitra ve ianareo alohan'ny amboly?*	Should you offer honey to *andriamanitra* before planting?
23	*Mametraka toaka-Gasy amin'ny andriamanitra ve ianareo alohan'ny amboly?*	Should you offer rum to *andriamanitra* before planting?
24	*Mametraka betsabetsa amin'ny andriamanitra ve ianareo alohan'ny amboly?*	Should you offer *betsabetsa* to *andriamanitra* before planting?

continued

No.	Malagasy	English
25	*Mila afangaro amin'ny salohim-bary henina voalazan'ny tangalamena vao azo ato ny fambolem-bary?*	Should you take six heads of rice to the *tangalamena* before harvesting?
26	*Mila hitsitsian'ny tangalamena vao azo volena ny vary?*	Should you pray with the *tangalamena* before harvesting?
27	*Mila mitondra masom-boly amin'ny tangalamena vao azo volena ny vary?*	Should you take paddy to the *tangalamena* before harvesting?
28	*Mila mitondra tantely amin'ny tangalamena vao azo volena ny vary?*	Should you take honey to the *tangalamena* before harvesting?
29	*Mila mitondra betsabetsa amin'ny tangalamena vao azo volena ny vary?*	Should you take *betsabetsa* to the *tangalamena* before harvesting?
30	*Mila mitondra toaka-Gasy amin'ny tangalamena vao azo volena ny vary?*	Should you take rum to the *tangalamena* before harvesting?

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