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Title: Engagement in agricultural work is associated with reduced leisure time among Agta hunter-gatherers

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A long-standing hypothesis suggests that the transition from hunting-and-gathering to agriculture results in people working harder, spending more time engaged in subsistence activities and having less leisure time[1,2]. Tests of this hypothesis are, however, obscured by comparing between populations that vary in ecology and social organisation as well as subsistence[3–6]. Here, we test this hypothesis by examining adult time allocation among the Agta, a population of small-scale hunter-gatherers from the northern Philippines who are increasingly engaged in agriculture and other non-foraging work. We find that individuals in camps engaging more in non-foraging work spend more time involved in out-of-camp work and have substantially less leisure time. This difference is largely driven by changes in the time allocation of women, who spend substantially more time engaged in out-of-camp work in more agricultural camps. Our results support the hypothesis that hunting-and-gathering allows a significant amount of leisure time and that this is lost as communities adopt small-scale agriculture.

Agriculture emerged independently in multiple locations worldwide from around 12,500 years BP and by 5,000 years BP had replaced hunting-and-gathering as the dominant mode of human subsistence[7,8]. The transition from foraging to farming is associated with population growth, sedentism, and the emergence of increasingly hierarchical political structures[6,7]. For individuals, the adoption of farming has been associated with an increase in fertility[9,10] and a decline in dietary breadth and overall health[11,12]. Although the transition from foraging to

farming could be readily explained if early farming were more productive than foraging, estimates suggest that this may not have been the case[2] and alternative hypotheses based on environmental, social, and demographic parameters have been proposed[13,14].

It has also been suggested that the transition from foraging to farming results in people working harder, having less leisure time, and being less productive per hour worked[2]. Based on data from contemporary hunter-gatherer societies, Sahlins[1] argued that hunter-gatherers represent the "original affluent society" who, despite a lack of material wealth, have a livelihood that allows them to work only 2-4 hours per day. Although this claim challenged the assumption that the foraging-to-farming transition represented an escape from an arduous foraging lifestyle, subsequent studies have found that there is substantial variation among foraging and farming populations in how much they work[3–6,15], that many hunter-gatherers face substantial annual fluctuations in food availability[6], and that many foraged foods require a substantial amount of time to process once brought back to camp[16]. Given this diversity, comparisons between populations are limited in their ability to isolate the effect of adopting agriculture on time allocation.

Here, we examine variation in time budgets within a single population – the Agta, a community of small-scale politically egalitarian hunter-gatherers from the northern Philippines who are increasingly engaged in agriculture and other non-foraging work[9,17–19]. The Agta live in small camps of fluid membership, within which individuals cooperate extensively in foraging and food sharing[20] and where ~50% of adults are distantly related or unrelated by kinship[21]. We conducted quantitative ethnographic fieldwork with the Agta in 2013 and 2014, collecting data on the time allocation of 359 people across ten camps (including 71 adult men and 71 adult women, >18 years). Time allocation data were collected through observational scans. We conducted four scans each day during daylight hours, with the first scan between 06:30 and 09:00 in the morning and three more at three-hour intervals. In each scan, we recorded the activity of all members of the community, grouping activities into four main categories: childcare, domestic chores, leisure, and out-of-camp work (see *Methods* for further details, Supplementary Table 1, Supplementary Figures 1-2). This resulted in a total of 10,706 person-observations. Out-of-camp work was divided into two categories: foraging and non-foraging work. Foraging work consisted of fishing, gathering, honey collecting and hunting. Although the majority of out-of-camp non-foraging work consisted of agricultural labour, this category also included activities such as the collecting of non-food items (such as rattan cane) to sell (see Supplementary Table 1 for activity frequencies by category).

Leisure time included socialising, resting, playing, and sleeping. Of adult leisure time (*N* observations = 1491), 71.9% was spent in close proximity to at least one other adult. Of this time, adults were in close proximity to an average of 2.20 other adults (SD = 2.23). There was no sex difference in the mean number of these social interactions (men: *N* = 546 observations, mean = 2.28, SD = 1.92; women: *N* = 526 observations, mean = 2.13, SD = 1.64, *P* = 0.11, two-tailed permutation test) and 49% of interactions between adults were with individuals unrelated through either genetic or affinal kinship.

By comparing across Agta camps that vary in their relative engagement in foraging versus non-foraging out-of-camp work, we are able to explore the association between changing livelihoods and time allocation. We show that across Agta camps, increased engagement in non-foraging out-of-camp work is associated with increased total out-of-camp work and reduced leisure time, and that there is a significant sex difference, with women significantly increasing their out-of-camp work as camps move away from foraging.

Across all camps, adults (*N* = 142) spent an average of 29.2% (SD = 22.0) of daylight time engaged in out-of-camp work (including both foraging and non-foraging work), 24.0% (SD = 12.0) engaged in domestic chores, 12.2% (SD = 15.6) engaged in direct childcare, and the remaining 34.7% (SD = 17.6) of time at leisure. However, there were significant sex differences in time allocation (Fig 1). First, although adult men spent significantly more time engaged in out-of-camp work and significantly less time engaged in domestic tasks and childcare than adult women (*N* men = 71, *N* women = 71; male out-of-camp mean = 41.1% (SD = 22.2), female out-of-camp mean = 17.3% (SD = 14.0), *P* <0.001; male domestic chores mean = 20.2% (SD = 11.2), female domestic chores mean = 27.7% (SD = 11.6), *P* <0.001; male childcare mean = 4.86% (SD = 8.54), female childcare mean = 19.5% (SD = 17.5), *P* < 0.001; two-tailed permutations tests; Fig 1), there was no significant difference in leisure time between adult men and women, with leisure representing approximately one third of daylight hours (male leisure mean = 33.8% (SD = 17.6), female leisure mean = 35.5% (SD = 17.7,) *P* = 0.28, two-tailed permutations test). For men and women over 50 years of age (*N* men = 17 men, *N* women = 12), a large proportion of daylight time was spent at leisure (men = 46.7% (SD = 19.5), women = 42.6%, SD = 15.6), with little direct engagement in childcare (men = 1.67% (SD = 5.60); women = 6.79% (SD = 9.83)). Individuals aged between 10-18 (*N* = 58) spent a similar proportion of their time engaged in out-of-camp work (40.7%, SD = 22.2) as at leisure (40.4%, SD = 19.9).

Adult time budgets were also affected by the demands of caring for young children, with the parents of children under the age of two years (the typical age of weaning) spending more time engaged in direct childcare than those with a youngest child between the age of 2 and 10 (women with youngest child <2yrs: N = 35, mean = 30.1% (SD = 14.8); women with youngest child 2-10yrs: N = 15, mean = 15.9% (SD = 16.8), P = 0.003; men with youngest child <2yrs: N = 33, mean = 7.93% (SD = 11.0); men with youngest child 2-10yrs: N = 13, mean = 1.92%, SD = 2.80, P= 0.044; two-tailed permutations tests, Fig 2c). For women, having a child under two also significantly decreased the total amount of time spent engaged in out-of-camp work (women with youngest child <2yrs mean = 12.9% (SD = 9.44); women with youngest child 2-10 years mean = 25.5% (SD = 18.2), P < 0.001; men with youngest child <2yrs mean = 44.1% (SD = 18.8); men with youngest child 2-10 years mean = 46.4% (SD = 29.0), P = 0.621, two-tailed permutations tests). Interestingly, the overall amount of leisure time remained similar across men and women with and without young children (Fig 2d).

Across the ten study camps, there was significant variation in engagement in non-foraging out-of-camp work, with non-foraging as a proportion of all out-of-camp work varying from 0% to 80%. Across the ten study camps, we found that greater involvement in non-foraging out-of-camp work as a proportion of all out-of-camp work was negatively associated with leisure time ($\beta(8)$ = -0.185, P = 0.031, t = -2.61, 95% CI = (-0.35, -0.02), linear regression, Fig 2a) and positively associated with total time spent in out-of-camp work ($\beta(8)$ = 0.164, P = 0.041, t = 2.43, 95% CI = (0.01, 0.32), Fig 2b). These associations appear to be driven largely by the increased involvement of women in non-foraging out-of-camp work, with a significant negative correlation between the relative engagement of camps in non-foraging out-of-camp work and the leisure time of women ($\beta(8)$ = -0.278, P = 0.003, t = -4.14, 95% CI =(-0.43, 0.122), Fig 2c) but not men ($\beta(8)$ = -0.090, P = 0.357, t = -0.98, 95% CI = (-0.302, 0.122), Fig 2c). There was no significant association between engagement in non-foraging out-of-camp work and time spent in domestic chores ($\beta(8)$ = -0.062, P = 0.293, t = -1.13, 95% CI = -0.187, 0.064).

In order to establish whether these results hold when controlling for differences in the age and sex composition of camps (Supplementary Table 2), we used Bayesian multilevel multinomial modelling[22] to predict adult leisure and work time across camps while controlling for the individual-level fixed effects of age, sex, and whether an individual had a child under the age of 2 years. This method also allowed us to take into account the multinomial nature of time-allocation data[23]. Confirming the previous linear regression results, the models suggested that for women but not for men, there was a negative association across camps between engagement

in non-foraging and predicted rest time (Supplementary Tables 3-4, Supplementary Figure 3). The results of this model provide a good fit to the data, confirm the age and sex related changes described above, and suggest little relationship between time of day and engagement in out-of-camp work (Supplementary Figures 4-6).

Our results provide evidence from within a single population of hunter-gatherers that greater engagement in farming and other non-foraging work is associated with increased out-of-camp work time and decreased leisure time. Although we cannot necessarily equate leisure time with affluence[6,24], given that previous studies have shown that more sedentary and agricultural Agta camps have worse health and increased child mortality (despite increased fertility rates)[9,25], the claim that the transition away from foraging among the Agta is associated with a deteriorated standard of living is broadly supported.

Although no activity was exclusively the domain of one sex, we found a general sexual division of labour among the Agta, with men doing more out-of-camp work than women and with women doing more childcare and domestic chores. In line with previous findings[6,20,26], this appears to be driven by the time constraints imposed on mothers by caring for young children. We also found pronounced age differences in time allocation, with adult leisure time increasing with age, and with out-of-camp work and childcare both peaking at ~30 years.

The negative relationship between leisure time and engagement in non-foraging out-of-camp work is driven largely by women, who spent much more time engaged in out-of-camp work and less time at leisure in those camps more heavily engaged in agriculture and other non-foraging work. Why is this the case? In part, it may be that agricultural work requires a greater total labour investment. Although this would be consistent with previous economic analyses of small-scale farming[2], it does not explain why the additional burden falls disproportionately on women. One possibility is that male and female agricultural work is more substitutable than foraging work, as may be the case where productive hunting or fishing requires many years of experience[27]. Alternatively, cultural norms relating to the sexual division of labour may apply differently to non-foraging work. Finally, men may be unable to spend additional time engaged in out-of-camp work without cutting into a minimum amount of required rest/leisure time. This would be consistent with analyses of time budgets in non-human primates[28], and with our finding that men and women had a similar amount of leisure time despite differing substantially in the amount of time devoted to other activities.

Although the differences observed in the relative engagement of Agta communities in foraging and farming provide a useful natural experiment for exploring the effect of economy on time allocation, extrapolation from our results to foraging-to-farming transitions in pre-history should be made with caution and particular attention should be given to the factors that may alter the relative productivity of foraging and farming among the Agta. For example, while the wet rice agriculture practiced in Palanan remains labour intensive and non-mechanised, it is likely to be much more economically productive than early farming[2]. Also, the Agta are able to increase the returns on foraging by trading with their non-Agta neighbours; they trade or sell approximately a quarter of all foraged food (and half of all foraged fish and meat) for rice and other agricultural products. This kind of protein-for-carbohydrate exchange is common between contemporary foragers and their farming neighbours[6,29] and may also reduce reliance on wild carbohydrates[30]. Finally, the livelihood of the Agta is influenced not only by their interactions with non-foraging neighbours but also by national policies relating to the status of indigenous people, land rights, and the environment[18].

Comparisons with farming aside, the amount of leisure time available to the Agta and other hunter-gatherers is testament to the success of the human foraging niche, made possible by our ability to share, process, and cook food, to make and use sophisticated tools, and to accumulate foraging skills and knowledge both within individual lifetimes and across generations[31,32]. These traits may themselves be promoted by having the leisure time to interact and exchange cultural knowledge with large numbers of people[32,33].

Methods

Ethnographic context

The Agta communities included in this study live in the coastal municipality of Palanan, which sits within the boundaries of the Northern Sierra Madre Natural Park, northern Luzon, Philippines. Within Palanan, as in the wider region, the Agta are a minority, accounting for ~5% of the population[18]. The Agta are politically egalitarian small-scale hunter-gatherers who cooperate extensively in childcare, foraging and food sharing[20,34] and have a flexible system of residence, with households moving frequently between camps. Many Agta families have long-standing trading relationships with non-Agta farmers and regularly trade foraged foods for rice and other agricultural goods as well as cigarettes, tools, alcohol, and household items. Across the four Agta camps for which data were available, the proportion of all foraged foods by weight that were sold or traded with non-Agta was 27.9% (Diago camp = 34.9%, Diabut camp = 18.8%, Diambarong camp = 31.3%, Dipagsangan

camp = 22.1%, based on the returns of 114, 49, 31, and 60 foraging trips respectively). This figure was greater for meat and fish, of which 50.7% by weight was traded or sold (Diago camp = 39.97%, Diabut camp = 56.6%, Diambarong camp = 82.1%, Dipagsangan camp = 46.2%, based on the returns of 60, 15, 20, and 28 fishing/hunting trips respectively). On average, the Agta received ~1.4kg of rice for 1kg of meat and ~1kg of rice for 1kg of fish. Assuming that meat, fish, and rice contain ~200, 100 and 350kcal per 100g respectively (based on United States Department of Agriculture estimates) trading of meat for rice and fish for rice yields a ~2.5 fold and ~3.5 fold increase in calories, respectively. These benefits, however, will be somewhat diminished by the travel costs associated with trade. The ten Agta communities included in this study have a mean size of 35.7 people (SD = 25.14, range = 17-100, Supplementary Table 2). Based on data derived from genealogical interviews we estimate that mean within group relatedness was $r = 0.12$ (SD = 0.04, range = 0.07-0.17) and mean within-group shared reproductive interest, a measure that captures relatedness through marriage[35] was $s = 0.15$ (SD = 0.05, range = 0.09-0.24).

Northeastern Luzon has a tropical climate with high humidity and heavy rains concentrated roughly between August and November and with several typhoons or tropical storms during this period each year. December and January are the coolest months and April-June are the hottest. Our time allocation data were collected between March and August 2014. During this time the weather was generally dry and hot, with no significant storms. At this time of the year, the Agta favour fishing over hunting because rivers are often calm and clear. The main agricultural activity in the region is wet-rice agriculture, a labour-intensive method of farming which can produce up to three crops each year. Most farms required labour throughout our March-August study period, harvesting at least one rice crop and planting another. Although few Agta own such rice fields themselves, they are involved in planting, tending and harvesting rice on farms owned by non-Agta. The observed differences in the engagement in agricultural work between Agta camps are largely a consequence of their proximity to farms and interest in engaging in this work, rather than temporal differences in opportunities for labour.

Data Collection

All data were collected in 2013 and 2014 as part of ethnographic fieldwork approved by the UCL Ethics Committee (UCLEthicscode3086/003). We explained our methods and data anonymity through presentations and posters in the local language, and received informed consent for all participants. Data collection and analysis were not performed blind to the conditions of the experiments. No statistical methods were used to pre-

determine sample size, which was determined by the size of the communities we had the opportunity to study. Time budget data were collected by conducting four observational scans each day at staggered intervals during daylight hours. We conducted the first scan between 0630 and 0930 and then recorded three more scans at three-hour intervals. In each scan, we recorded the activity that each member of camp was engaged in, entering data on individuals as we encountered them. Agta camps are typically concentrated in a small area and the activities of most individuals are visible from a central place. When individuals were out of camp, we asked those in camp what the absent individuals were doing, and verified this when the individual returned. In some cases, one of the authors was present with individuals on out-of-camp work. Time spent by individuals in other camps was excluded from our data and, similarly, we excluded visitors to our study camp, including only individuals who spent four days or more in the study camp. For those individuals who were present, we also recorded the individuals to whom they were in close proximity (~10m). Our time allocation categories were modified from those developed for the Agta in a previous study[18] and are given in Supplementary Table 1. In some observations, individuals were engaged in more than one activity concurrently (for example an adult carrying a child while foraging). In these cases, in order to preserve the multinomial structure of the data, we randomly selected one of the concurrent activities. Our analyses focus on differences in time spent at leisure and at work between camps. This allows us to overcome the high degree of interdependence in the time budgets of individuals and the relatively modest number of observations per individual (mean observations per adult = 30.09, range = 18-56, SD = 7.87). Among the Agta, we rarely encountered individuals who knew their own age. To estimate age, we took the mean values from posterior probability distributions of age produced using a Gibbs sampling MCMC algorithm based on age ranking order data provided by the Agta and a plausible a priori age range for each individual provided by the ethnographers[36].

Statistics

All analyses were conducted in R.3.5.1. We used an alpha level of .05 for all statistical tests. Variables used in the regression analyses met the assumption of normality. To evaluate the statistical significance of pairwise differences in time allocation between age and sex categories, we compared the observed differences between categories with expected distributions generated by resampling from the original data 10,000 times. To explore the influence of engagement in non-foraging activities on leisure time, we fitted Bayesian multilevel multinomial models in the *brms* package[22]. These models capture the multinomial nature of time budget data whilst allowing for the investigation or control of both fixed and random effects. We fitted separate multinomial

models for adult males and females where the response variable considered five activities: childcare, domestic chores, foraging work, non-foraging work, and leisure. 'Domestic chores' was set as the reference category, so that each model predicts the log-odds ratio of the proportion of time engaged in each activity relative to the proportion of time engaged in domestic chores. In each model, we included a random effect of individual to control for non-independence of data collected repeatedly from the same individuals, and fixed effects of age, age^2, age^3, in addition to a term for the time of day and its quadratic. Importantly, we also included a categorical variable for camp, so that, having controlled for variation in age and time of day, we could then compare the predicted time budgets of individuals across camps. Each model was fitted with three chains of 3000 iterations, of which 600 were used for the warm-up. Population-level effects were scaled before model fitting. We chose normal priors for all population-level effects (mean = 0, standard deviation = 8). Model diagnostics highlighted adequate mixing of chains, and the correspondence between posterior predictive distributions and the observed data was high (Fig S5).

Code Availability

The code used to analyse the relevant data is provided as Supplementary Software.

Data Availability

The individual-level data that support the findings of this study are available from the corresponding author upon reasonable request. Any further work on the data depends on community approval.

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Contributions

M.D. conceived of the study and wrote the manuscript; data analysis by M.D. and J.T.; data collected by M.D., A.E.P., D.S., and A.B.M; all authors discussed the results and contributed towards improving the final manuscript.

Competing interests

The authors declare no competing interests.

Figure 1 | **Age and sex differences in time allocation.** Proportion of time spent engaged in **a** domestic chores, **b** childcare, **c** out-of-camp work, and **d** leisure activities of individuals across all camps. Solid red lines are female, dashed blue lines are male. Data for all individuals aged >3.5 years old, N = 151 male, N = 135 female in all panels. Curves are LOESS (locally estimated scatterplot smoothing) with a 95% confidence interval, computed with span = 0.75 and degree = 2. Triangles = mean values for individual males, circles = mean values for individual females.

Figure 2 | Differences in time allocation between camps and between adults with and without young children. Association between non-foraging as a proportion of all out-of-camp work and **a** adult daylight leisure time, **b** adult daylight out-of-camp work time, and **c** adult leisure time split by sex across the ten study camps.

Lines are the slopes from linear regressions described in the main text and dotted lines in **a** and **b** are the 95% confidence intervals. **d** time allocation of adult women and men with a youngest child under the age of 2 years and a youngest child between the age of 2 and 10 years (*N* women with child <2yrs = 35, *N* women with child 2-10yrs = 15, *N* men with child <2yrs = 33, *N* men with child 2-10yrs = 13) Child = childcare, Dom = domestic chores. *Out-of-camp work.