Modelling latrine diffusion in Benin: towards a community typology of demand for improved sanitation in developing countries

Marion W. Jenkins and Sandy Cairncross

ABSTRACT

Latrine diffusion patterns across 502 villages in Benin, West Africa, were analysed to explore factors driving initial and increasing levels of household adoption in low-coverage rural areas of sub-Saharan Africa. Variables explaining adoption related to population density, size, infrastructure/services, non-agricultural occupations, road and urban proximity, and the nearby latrine adoption rate, capturing differences in the physical and social environment, lifestyles and latrine exposure involved in stimulating status/prestige and well-being reasons for latrine adoption. Contagion was most important in explaining adoption initiation. Cluster analysis revealed four distinct village typologies of demand for latrines which provide a framework for tailoring promotional interventions to better match the different sanitation demand characteristics of communities in scaling-up sanitation development and promotion programmes.

Key words | Africa, behavior change, cluster analysis, innovation adoption, latrines, spatial analysis

Marion W. Jenkins (corresponding author)
Department of Civil and Environmental Engineering,
University of California at Davis,
One Shields Avenue,
Davis, CA 95616,
USA
Tel.: +1-530-754-6427
Fax: +1-530-752-7872
E-mail: *mwjenkins@ucdavis.edu*

Sandy Cairncross
Disease Control and Vector Biology Unit,
Room 402,
London School of Hygiene and Tropical Medicine,
Keppel St,
London WC1E 7HT,
UK
Tel.: +44 20 7927 2211
Fax: +44 20 7636 7843
E-mail: *sandy.cairncross@lshtm.ac.uk*

INTRODUCTION

Two in five of the world population still lack adequate basic sanitation. This neglected public health challenge has persisted for decades. In rural sub-Saharan Africa, where only 26% of people had access to an adequate facility in 2002, the challenge is greatest. While now part of the Millennium Development Goals, this need will remain unmet unless household demand for toilets from the un-served can be stimulated. On-site low cost sanitation in the form of a latrine or pit toilet has long been recognized as the most appropriate rural solution. However, with limited resources in developing countries, promoting the adoption of latrines remains a highly uncertain endeavour. In practice, rural sanitation programmes and projects operate with little understanding of the local and regional drivers of uptake, frequently resorting to across-the-board subsidized latrine construction. Development organizations, faced with frequent failure of these supply-driven interventions, have called for approaches that stimulate and respond to community and household demand (Cairncross 1992; Lafond 1995; UNICEF 1997; Wright 1997; WELL 1999). The need to stimulate demand for sanitation has led to experimentation and emergence of new promotional approaches (Simpson-Hebert *et al.* 1997; Kar 2003; Cairncross 2004; Frias & Mukherjee 2005; Waterkeyn & Cairncross 2005).

Experience in rural water supply has shown that effective development policy must consider what consumers want and will pay for (World Bank Water Demand Research Team 1993). Through a regional analysis of the determinants and patterns of latrine adoption behaviour across a comprehensive set of villages within one region of Benin, and development of a classification scheme based

doi: 10.2166/wh.2009.111

on key determinants, this research aims to develop practical guidance for regional planning and strategic adaptation and targeting of demand-responsive interventions to accelerate household adoption of improved sanitation in low coverage areas, one that takes into account the role of village characteristics in differentially shaping demand for improved sanitation in sub-Saharan Africa. For discussion of the definition of household demand for improved sanitation, see Jenkins & Scott (2007). The study also demonstrates the potential of existing geographic, census and infrastructure datasets to support more effective use of resources for sanitation programming at scale in developing countries, even in poorer African countries such as Benin.

This paper draws on 1993 comprehensive data on household latrine adoption in Zou Department (now split into Zou and Collines) in Benin, using census administrative villages as the unit of analysis. Overall the low level of latrine installation in 1993 (5 to 7% of rural Zou households by 1996; the remainder practising traditional open defecation) can be characterized as the spontaneous behaviour of some households early in the introduction and diffusion of a technology innovation (Rogers 1983; Jenkins 2004). Household latrines were nearly 100% privately financed and locally built (Alihounou *et al.* 1995); development efforts focused on building institutional latrines. Thus, latrine adoption patterns in 1993 provide a snapshot of the diffusion process free from confounding by external sanitation development initiatives.

Research began by developing a set of hypothesized spatial and non-spatial variables from available datasets to explain latrine adoption diffusion patterns at the village level, based on prior knowledge of motivations for and constraints on household latrine adoption in rural Benin. A subset of core explanatory variables emerging from regression modelling was then used in cluster analysis to identify four distinct community types, in terms of their different demand characteristics for improved sanitation. The aim here was to identify determinants of latrine demand at village level, not primarily so that they could be altered, but so that rural populations lacking improved sanitation could be divided into segments based on their differing demand characteristics, and a promotional intervention strategy devised which is appropriate to each.

HOUSEHOLD DECISION TO ADOPT LATRINES IN RURAL BENIN

Previous in-depth research demonstrated that the decision to install a latrine for the first time takes place in a household in rural Benin when awareness and motivation to build a household latrine are sufficiently strong and constraints against installation are limited or absent (Jenkins 2004). Motivation was characterized as reflecting the arousal of a 'desire for change', developed in response to three underlying forces: physical and social conditions of the village environment, individual lifestyle goals and past latrine exposure (Jenkins & Curtis 2005). This earlier motivation research in Benin identified 11 different desires for change, encompassing prestige/status-related, well-being and situational goals. To affiliate with the urban elite and to express new experiences and a lifestyle acquired outside the village were two status-related reasons linked to specific lifestyle characteristics. Well-being reasons included desires for greater cleanliness, health and safety, convenience and comfort, and privacy, all linked to perceptions of changes in the physical and social environment that made traditional open defecation unattractive. Decreasing availability of open defecation sites, increasing socio-economic differentiation, and increasing numbers of outsiders engendered greater felt needs for privacy, protection of health and safety, convenience and status symbols. Larger village size, greater occupational diversity, presence of commercial or governmental activity, level of infrastructure, road access and urban proximity were found to be associated with these kinds of physical and social change to the village environment in Benin (Jenkins & Curtis 2005).

Sufficient awareness and understanding of household latrines is also needed before one can consider installing a latrine, and in rural areas of Africa is likely to develop from exposure to household latrines (e.g. at a relative or friend's home) and through interpersonal communication (Rogers 1983). With more household latrines installed in a village or in the vicinity, residents are likely to become more informed and aware, and the technology more accessible. Greater contact with urban areas where latrines are more common is likely to increase awareness.

DATA, VARIABLES AND MODELLING APPROACH

Zou Department in 1993 was divided into 15 sub-prefectures, 132 communes and 720 administrative villages (INSAE 1994). Each sub-prefecture and commune had an administrative capital or seat. Of the 720 villages, 24% were located in communes classified as 'urban', in which the sub-prefecture capital was located.

Existing village datasets from 1994 and 1995 were obtained from three different agencies in Benin. The Ministry of Energy, Mines and Water provided a database on rural water supply, population and other infrastructure for all 720 Zou villages and GIS data and layers of village location, administrative boundaries and road networks. UNICEF provided data from the 1993 National Guinea Worm Disease Survey conducted across 536 Zou villages identified in 1989 as endemic, which counted the number of household latrines in each village. The National Institute of Statistics and Economic Analysis (INSAE) published data from Benin's second National Census (1992) comprising total and agricultural population and households (the difference being those engaged in non-agricultural occupations) for 703 Zou villages (INSAE 1994). Coding, cleaning, merging and quality control procedures performed in SPSS to unify the three datasets into a single database consisted of:

- Verifying accuracy of village identification codes in each database by matching sub-string codes to sub-prefecture, commune and village name, and correcting errors where possible
- Manually flagging and correcting or removing records with the same identification code
- Automatic checking and converting geographic coordinates from alphanumeric degrees, minutes and seconds to decimal values for mapping in GIS software
- Manually flagging and correcting or removing villages with locations outside their sub-prefecture or commune
- Successively merging the three databases (720, 703 and 536 records) by matching village identification codes and correcting or flagging for removal, mismatched or unmatched records, at each merge step

The merged dataset contained 521 valid village records of which four had no latrine data and 15 had unusable coordinates. As expected, these 521 villages were significantly more rural in character than the remaining 199 villages (Guinea worm disease is associated with rural areas with poor water supply). Fewer were in urban communes (20% compared with 33% for the 199 remaining villages) and on average, populations were more agricultural (84% compared with 78%) ($p < 0.001$).

Latrine adoption patterns and variability

In the 502 villages with dependent and spatial data required for analysis, installed household latrines varied from 0 to 374. Household adoption rates varied from 0 to 95.8% (a likely outlier), with a mean of 4.8% (Table 1). Although these rates may lack some accuracy (numerator and denominator from different sources), they indicate order of magnitude differences in adoption levels. Nearly 40% of villages had no latrines at all. In others, demand was evident and being met by local private market solutions. Visual inspection and spatial analysis of the geographic pattern of household adoption levels (Figure 1) show latrine adoption spreading outwards from urban centres, especially the main twin towns of Abomey (Zou Department's capital) and Bohicon, and along road networks, patterns typical of a spatially controlled diffusion process (Rogers 1983). In the 20 km area around Abomey-Bohicon (Figure 2), adoption rates dropped steadily from a high of 12.3% of households in the 3 to 5 km band from the twin centers, to a low of 1.4% of households in the 15 to 20 km band.

Table 1 | Latrine adoption in 502 villages of Zou Department in Benin in 1993

Latrine adoption rate (% of households)	Villages	% Villages
0	195	39
0 to 2	86	17
2 to 5	91	18
5 to 10	65	13
10 to 25	47	9
25 to 50	14	3
Greater than 50	4	1
All	502	100

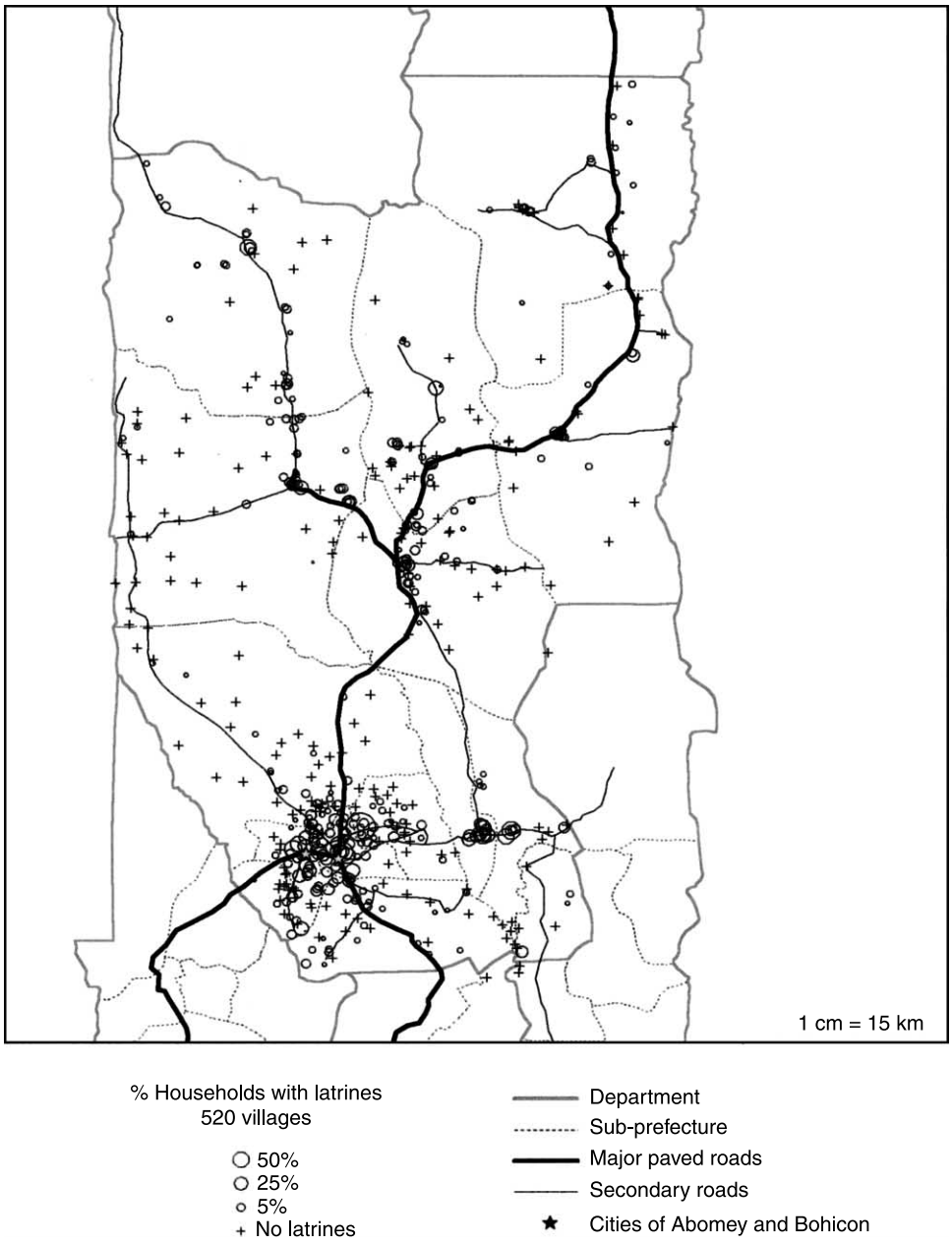

Figure 1 | Household latrine adoption in 502 villages of Zou Department, Benin, 1993.

Independent variables

Using the merged GIS dataset and layers, 11 indicator variables were constructed, capturing potential village environment (VE), individual lifestyle (I) and latrine exposure (LE) characteristics, drawing on knowledge about latrine adoption decision behaviour and motivation (Jenkins 2004; Jenkins & Curtis 2005), to explain observed variations in pit latrine adoption across rural Zou villages. Table 2 defines each variable, its type (VE, I, LE) and hypothesized influence. Direction of influence recognizes the likelihood that some indicator variables represent multiple influences on adoption, including ones related to opportunities and abilities needed to install a latrine (Jenkins & Scott 2007). Six additional variables, less easily categorized, are included at the end of Table 2.

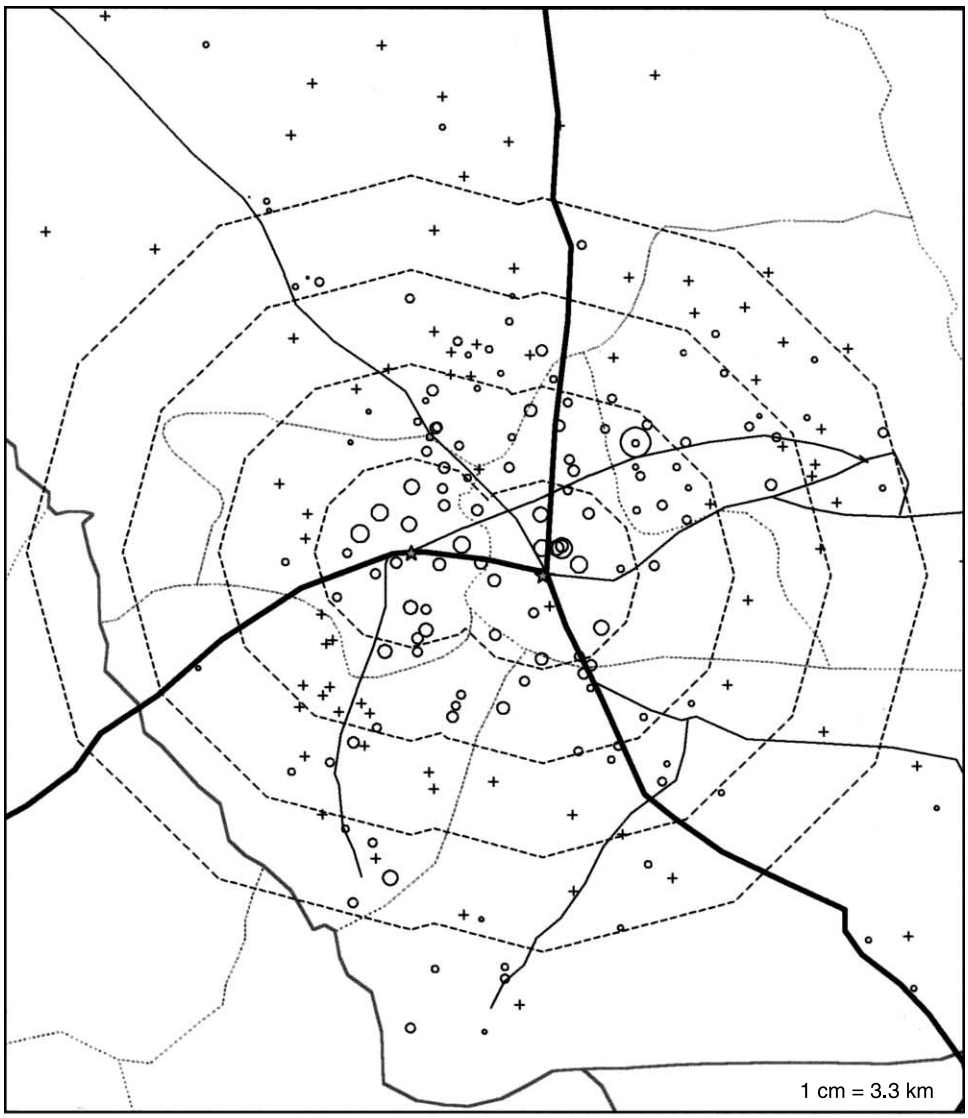

Figure 2 | Household latrine adoption in villages located within 20 km of Abomey-Bohicon, Zou Department, Benin, 1993.

Dependent variables

Percentage of households with installed latrines was problematic as a dependent regression variable because it used a numerator from a different data source (1993 National Guinea Worm Survey) from that of the denominator (1992 INSAE Census) and is truncated at 0 and 100. For many villages, the number of households (a concept difficult to define and measure accurately in sub-Saharan Africa) diverges between the two datasets, causing uncertainty about the true percentage of households with latrines. Two dichotomous logistic regression variables in Table 3 address threshold-related questions about village latrine

Table 2 | Village-level variables, definitions and characteristics hypothesized to influence household latrine adoption

Variable name	Variable definition	Indicated characteristic or driver	Type*	Direction of influence
Size†	Population	Socio-economic and ethnic differentiation, lack of cohesion and other social/physical changes to the village landscape associated with larger size	VE	+
Population density‡	Population within 2.5 km radius of village divided by area (persons km^{-2})	Reduced availability of open defecation sites	VE	+
Socio-economically homogeneous†	95% or more of population is engaged in agriculture	More traditional, socio-economically undifferentiated agricultural community	VE	−
Infrastructure level§, ‖, ¶	0 = infrastructure index points of 0 or 1 1 = infrastructure index points of 2 or 3 2 = infrastructure index points > 3	Greater infrastructure and services development, capturing social heterogeneity, improved water access, greater commercial and public activities, regional integration and modernizing influences, which may simulate greater desires for latrines	VE	+
Fraction non-agricultural population†	Fraction of population engaged in non-agricultural occupations	Occupation-induced lifestyles with greater prestige/status and well-being desires for latrines (Jenkins & Curtis 2005)	I	+
Agricultural household size†	Agricultural population/agricultural households	Wealthier agricultural households (Kamuzora 2001)	I	+
Non-agricultural household size†	Non-agricultural population/non-agricultural households	Uncertain, possibly more traditional marriage/family size orientation or less wealth (Kamuzora 2001)	I	?
Nearby latrine adoption rate†, ‡, §	Latrine adoption rate of households surrounding the village, within 2.5 km radius (excluding the village itself)	Greater local opportunities for exposure to private latrines in nearby areas surrounding the village; perhaps also greater access to latrine technology	LE	+
Proximity to Abomey-Bohicon‡	1/square root of the straight-line distance between village and Abomey-Bohicon	Increased linkages to urban society and culture, and perhaps greater access to latrine technology	LE/VE	+
Far from any road‡	Located more than 5 km from paved and dirt roads	Isolation, lack of exposure to new ideas, lack of mobility and travel	LE	−
Near paved road‡	Located within 2 km of a paved road	Road access/proximity, greater exposure to new ideas, mobility and travel, greater potential for crime	LE/VE	+
Urban commune†	Located within one of 15 urban-designated communes where each sub-prefecture administrative centre is located	Proximity to a local town with some urban development (i.e. electricity, transport, secondary school, regional markets)	?	+

Table 2 | (*continued*)

Variable name	Variable definition	Indicated characteristic or driver	Type*	Direction of influence
% reduction non-agricultural from average household size†	Deviation of non-agricultural household size below the average household size measured as a percentage of the latter; large positive number indicates presence of a few very small non-agricultural households; large negative number indicates a few relatively large non-agricultural households	Relatively small number of non-agricultural households, considerably smaller than average size households that may indicate either very modern lifestyles or poor disenfranchised households (Kamuzora 2001)	I?	?
Piped water neighbourhoods§	Number of neighbourhoods/hamlets within village with piped water access	Predisposition to adopt such services; piped water also creates demand for improved hygiene (Curtis *et al.* 1995)	I?	+
School§	Primary school in the village	Modern/change-oriented village; 1 latrine provided for school director	LE?	+
Clinic§	Health clinic in the village	Exposure to health messages about sanitation, using latrines, and faecal-oral disease prevention	LE?	+
Growth rate‖	Annual population growth rate in 1979–92, 1984–92 or 1988–92	Either economic vigour and in-migration, or high fertility indicating traditional lifestyles	?	?

*Type of influence represented, where VE = village environment, I = individual lifestyle, and LE = latrine exposure (see Jenkins & Curtis 2005).

†1992 Census data or computed from it.

‡Spatially computed using geographic data and GIS software tools.

§1993 National Guinea worm survey data or computed from it.

‖Water Ministry data or computed from it.

¶Created by summing a point each for presence of primary school, secondary school, local market, regional market, clinic, handpump and piped water in the village.

? Uncertain what type and direction of influence this variable exerts on demand.

Table 3 | Binary logistic regression models of village latrine adoption

Name	Model explanation	Variable definition	# of villages	Household adoption rate (%)
Any latrines	Identifies characteristics that explain initiation and presence of latrine adoption	1 = village with 1 or more latrines	307	7.8
		0 = village with no latrine	195	0
Many latrines	Identifies characteristics that explain higher demand for latrines	1 = village with over 10 latrines	120	15.3
		0 = village with 1 to 10 latrines	187	3.0

adoption and overcome truncation problems (Hosmer & Lemeshow 1989). Given uncertain accuracy for number of households, these were judged more appropriate than a continuous variable, and allow for potential non-linear influences of independent variables on adoption patterns as demand develops. 'Any latrines' separates villages with no latrines from those with some, to focus on the initiation and presence of adoption in a village. 'Many latrines' separates villages with more than ten latrines from those with one to ten to focus on conditions that explain the presence of 'strong' demand or higher levels of private latrine adoption in a village. Higher cut-off levels were explored but these quickly reduce the share of 'strong' demand villages, leading to models whose explanatory power is dominated by the constant term (Ben-Akiva & Lerman 1985). Adoption rates and observed shares are reported in Table 3.

Logistic regression models of 'any' and 'many latrines' allow exploration of relationships between village conditions and adoption behaviour at two different stages in the diffusion process. The former model is expected to capture the controlling effects of factors exogenous to a village, on initial introduction of latrines in a village, while the latter would capture the acceleration or 'take-off' of village adoption where endogenous factors might be expected to control (Rogers 1983; Gatignon & Robertson 1985).

Descriptive statistics and data quality

Descriptive statistics for the full set of 502 villages appear in Table 4. A significant amount of colinearity existed among the 17 independent variables of Table 2. Pearson correlation values of 0.50 occurred for some variable pairs (e.g. population density and fraction non-agricultural population). A subset of villages with highly correlated household data from census and UNICEF sources has nearly the same characteristics as the full set. By some standards, quality and accuracy of these data may not appear particularly good for quantitative modelling. Nonetheless, given limited amounts of coherent regional data in developing countries, particularly in Africa, obtaining secondary data such as this, at zero collection cost, even of suspect quality, is fortunate. Regression results show it is still possible to draw meaningful and important conclusions from such data.

Modelling approach

Given colinearity among the independent variables, stepwise forward regression was chosen to identify significant determinants of latrine demand (Neter *et al.* 1990). Significance limits were varied and finally set at 0.35 for entry and 0.5 for removal, balancing increases in explanatory power, improvements in correctly predicted outcomes, and reductions in independent variable significance.

REGRESSION MODELLING RESULTS

Modelling results are summarized and two representative models presented (Table 5). Several other dependent variables and data subsets were tested; however, all included a consistent subset of significant variables. Variables without reported coefficients in Table 5 did not meet the stepwise significance limits for inclusion. Goodness-of-fit is measured by ρ^2 and adjusted $\rho^2(\beta/c)$ for logistic regression models, the latter indicating improved fit of the included variables (β's) over a model having only

Table 4 | Descriptive statistics for Zou village dataset ($N = 502$)

Variable	Mean	Min.	Max.	SD
Continuous variables				
Size	1,209	84	9,050	933.7
Population density (persons km^{-2})	310.0	4.3	2291	357.1
Fraction non-agricultural population	0.170	0	0.925	0.201
Agricultural household size	6.05	2.20	11.31	1.28
Non-agricultural household size	3.80	0	23	1.85
Nearby latrine adoption rate	0.034	0	0.821	0.058
Proximity to Abomey-Bohicon	0.212	0.073	1.456	0.156
% reduction non-agricultural from average household size	29.23	−269.8	98.1	27.60
Piped water neighbourhoods	0.32	0	11	0.92
Household latrines	13.2	0	374	37.1
Growth rate	0.033	−0.313	0.466	0.076
Categorical variables[*]				
Socio-economically homogeneous	0.32	0	1	0.47
Infrastructure level (0,1,2)	0.75	0	2	0.66
Near paved road	0.63	0	1	0.48
Far from any road	0.16	0	1	0.37
Urban commune	0.21	0	1	0.41
School	0.66	0	1	0.48
Clinic	0.36	0	1	0.48
Dependent variables				
Village with any latrines	0.61	0	1	0.49
Village with more than 10 latrines	0.24	0	1	0.43

[*]Yes = 1; no = 0, mean value is fraction of 'yes' villages, except infrastructure level.

a constant (c), adjusted for degrees of freedom taken up by the variables (Ben-Akiva & Lerman 1985; Hosmer & Lemeshow 1989). Commonly, ρ^2 values for logistic models tend to be lower than R^2 values in linear models (Ben-Akiva & Lerman 1985). Logistic models are also judged by correct predictions (Table 5), both with and without the constant. Considering data limitations and omission of unobserved factors, the predictive validity of modelled factors is surprisingly good.

Significant variables and hypothesized influence on demand

All the proposed variables in Table 2 were included ($p < 0.25$) in one or more regression models tested except for non-agricultural household size, near paved road, urban commune and clinic. All included variables influence demand in the direction predicted. The most consistent village characteristics stimulating demand for latrines are size, population density, non-agricultural occupations and local opportunities for exposure to private latrines. Other influential characteristics include infrastructure development, proximity to a road, proximity to the major urban centre, agricultural household size, presence of piped water, presence of a school and growth rate. Existence of a few relatively small non-agricultural households positively influences initiation of adoption, but negatively influences the likelihood of higher levels of private latrine adoption in the strong demand model. While neither effect is statistically significant, they are not inconsistent, if this variable indicates the presence of a small number of government/salaried workers assigned to rural areas in Benin who

Table 5 | Logistic regression models of village latrine adoption in Benin

Model N	Any latrines 502		Many latrines* 307	
Variables	**Coefficient**	**Sig.†**	**Coefficient**	**Sig.†**
Constant	−1.34	<0.0001‡	−4.06	<0.0001‡
Population size	0.0005	0.033‡	0.0006	0.010‡
Population density (5 km)	0.0009	0.198	0.0026	<0.0001‡
Socio-economically homogeneous	−0.776	0.006‡	−0.858	0.169
Infrastructure (level 1)			0.909	0.025‡
Infrastructure (level 2)			1.82	0.001‡
Fraction non-agricultural population	2.66	0.035‡	1.33	0.234
Agricultural household size				
Non-agricultural household size				
Nearby latrine adoption rate	20.98	<0.0001‡	4.36	0.066
Proximity to Abomey-Bohicon			3.84	0.007‡
Near paved road				
Far from any road	−0.610	0.055		
Urban commune				
% reduction non-agricultural from average household size	0.0083	0.087	−0.017	0.098
Piped water			0.314	0.143
School	0.688	0.008‡		
Clinic				
Growth rate	−3.55	0.029‡		
ρ^2	0.311		0.406	
Adj ρ^2 (β/c)	0.259		0.341	
Correct predictions–overall	76.5%		82.7%	
Correct positive predictions ($y = 1$)	82.7% ($n = 307$)		73.3% ($n = 120$)	
Correct negative predictions ($y = 0$)	66.7% ($n = 195$)		88.8% ($n = 187$)	
Correct predictions no constant –all	75.5%		78.2%	

*i.e. more than 10 blank spaces indicate variables which did not meet criteria for entry and retention in model.
†Significance of the wald statistic.
‡Indicates variable significant at the 0.05 level.

typically leave their family behind in the city, and is associated with the rather limited situational goal to install latrines for rental income in these villages (Jenkins & Curtis 2005).

In nearly all models of strong demand, the first variable entered was fraction non-agricultural population followed by population density. In all 'any latrines' models, nearby latrine adoption rate was entered either first or second. In Benin, health education at clinics in 1993 included messages about the use of latrines to prevent faecal-oral transmission of disease. Absence of clinic as a driver of adoption is consistent with other findings that health messages about sanitation fail to motivate latrine adoption (Cairncross 1992, 2004; Jenkins & Sugden 2006). The negative coefficient on growth rate supports association of this indicator with higher fertility rates and more traditional agricultural lifestyles, and less arousal of desires for latrines.

Factors explaining the initiation of latrine adoption

In the adoption initiation/presence model, the most significant village characteristics were presence of non-agricultural households, the latrine adoption rate in the

surrounding area, and presence of a school. The coefficient on nearby latrine adoption rate is extremely large and highly significant, in contrast to the strong demand model. The role of school in predicting the presence of at least one latrine in a village (but not strong demand) may be an artefact of a latrine at the school director's house, provided by the state. In many small villages, the director's house is the only one with a latrine. While size and population density are included in the adoption initiation model, they have smaller and less significant effects than in the strong demand model. Noticeable are absence of proximity to Abomey-Bohicon, neighbourhoods with piped water and infrastructure as significant explanatory variables for adoption initiation. These results suggest private latrine exposure through proximity is the most important condition explaining the initiation and presence of adoption in a village.

Factors influencing higher levels of latrine adoption

Stronger expressed demand for latrines in a village, as measured by higher levels of adoption, appears stimulated by factors associated with: higher population densities, larger size (but not rapid population growth), infrastructure development and proximity to the urban centre. Additional factors explaining stronger demand, though not significant at the 0.05 level in the model shown in Table 5, are an increasingly non-agricultural population, increasing availability of piped water, larger agricultural household size, and higher nearby latrine adoption rate. The adoption rate in the surrounding area may simultaneously capture the presence of facilitating opportunity factors including access to skilled labour, materials and technical information. Differences between model determinants of initiation and 'strong' demand are consistent with diffusion theory's notion that exogenous factors control the start of adoption while endogenous ones determine its rate and level of penetration within a social group or area (Rogers 1983; Gatignon & Robertson 1985). The set of analysed independent variables distinguish between villages with strong and weak demand (high and low latrine adoption levels), better than they distinguish villages with any adoption from those with none.

Contagious effects of latrine adoption

The only household lifestyle-related factors whose influence could be tested explicitly in these analyses were occupation and wealth (using a weak proxy). While it is not possible to say whether village environment or individual lifestyle factors are stronger determinants of demand for latrines, the order of variables entered suggests that lifestyle (fraction non-agricultural occupations) may be more fundamental to arousing demand, at least in this early stage of adoption diffusion. Distinguishing between village environment and individual lifestyle factors parallels the notion of public and domestic domains in disease transmission (Cairncross *et al.* 1996). For example, surrounding household latrine adoption rate was an important influence on demand in every model tested. If latrine ownership is thought of as an infection, its prevalence definitely increases when more of one's neighbours own a latrine. This is consistent with diffusion theory, the laws of imitation, the apparent symbolic and status carrying value of latrines in rural Beninese society (Jenkins & Curtis 2005), and the need for substantial amounts of evaluation for adoption to occur (Gatignon & Robertson 1985). Contextual aspects of visual exposure to private latrines may be critical for conveying the cultural meaning and symbolic value of latrines operating in arousing status/prestige drives in Benin. Local exposure opportunities also provide occasions for experimentation and personal evaluation of an innovation needed for adoption (Rogers 1983).

The regression modelling results have enhanced our understanding of latrine demand, but are not a basis for a latrine promotion strategy; most of the factors identified (e.g. population density, size) are not susceptible to manipulation. Latrine exposure, however, is one factor that can be manipulated through interventions. Development of a viable promotional strategy requires division of the market into homogeneous segments or clusters; this is discussed in the following section.

CLUSTER ANALYSIS OF SANITATION DEMAND VILLAGE TYPES

Cluster analysis was undertaken with a subset of variables to develop a community typology of demand for improved

sanitation based on the regression results. K-means cluster analysis was used, where the number of groups is specified a priori (Lorr 1987; Norusis 1994). Three to four village types were determined to be a reasonable number of groups to interpret. The four-cluster solution produced a greater number of statistically significant distinct characteristics and more interpretable types with regard to administrative and geographic structure at the regional scale.

Cluster analysis variables

A subset of 439 villages was included in the analysis, after removing 63 villages with unreasonable values or values more than three standard deviations from the mean. Many of these were actually neighbourhoods located on the urban fringes of Bohicon, Abomey and Cove (a smaller urban centre, east of Bohicon). The following five key variables from Table 2 provided the basis for village classification into four clusters: size, population density, infrastructure index, fraction non-agricultural population and near paved road. Latrine exposure variables were excluded because sanitation promotion can be designed to modify exposure to latrines from that occurring naturally by diffusion; for example, through awareness-raising campaigns, toilet demonstration and information centres, and facilitated local access to technical and implementation services (Gatignon & Robertson 1985). Although near paved road was classified in Table 2 as a latrine exposure factor, it is included here because proximity to a road is also thought to indicate unique village and lifestyle factors that arouse desires for change for a latrine in rural Benin, such as a greater felt need for safety at night, exposure to new ideas and information and modern attitudes (Jenkins & Curtis 2005).

Cluster results

Mean cluster characteristics are reported in Table 6. The first five values define the four cluster centres. Values for the remaining variables provide further characterization of each group. One-way ANOVA comparing mean values across groups is significant (at the 0.05 level) for all variables except proximity to Abomey-Bohicon and % reduction non-agricultural from average household size. Average village size and population density by cluster are plotted for comparison (Figure 3), as are 1993 village latrine adoption levels (Figure 4).

Sanitation demand characteristics of four emerging village types

Four distinct types of village with respect to drivers of latrine adoption emerged from cluster analysis: (1) high density, economically diverse 'small urban fringe'; (2) large, non-urban 'agricultural sub-prefecture centre'; (3) smaller, but integrated 'commune seat'; (4) administratively unimportant, isolated, agriculturally homogeneous 'small remote'.

Type 1 comprised a small group of 1993 Zou villages with no administrative function, located mostly in urban communes, fully integrated by road, and located close to large urbanized sub-prefecture capitals that form the first level in a hierarchy of Zou Department settlements (see Morrill & Dormitzer (1979) on spatial hierarchies in geography). Type 1 villages are bedroom communities for their adjacent urban centres, and more likely to have piped water, perhaps electricity, but not much other infrastructure. Highest levels of latrine demand in 1993, by all measures, occurred in Type 1 villages (Figure 4), due to their higher percentage of non-agricultural households, greatest population densities (Figure 3), socio-economic diversity, and highest latrine exposure opportunities, which combined, are thought to contribute to greater arousal of both prestige and well-being drives for latrines (Jenkins & Curtis 2005). Latrine adoption was under way in nearly all Type 1 villages, and over 60% had more than 10 installed latrines ('strong' demand). About 6% of Zou's 1993 rural population lived in Type 1 villages.

Large agricultural centres, often the capital seat of less urbanized sub-prefectures, or the principal village of more important communes characterize Type 2 villages. They tend to comprise the second level in the Zou hierarchy of population centres, being spread out from each other, located on unpaved main roads, and relatively far from urban centres. High population densities in the centre tended to drop off quickly in surrounding areas (Figure 3). They had some piped water supplies, but were unlikely to have electricity. They had greater levels of infrastructure

Table 6 | Characteristics of four village types * for rural latrine demand in Benin

Cluster/Type	1	2	3	4		
Label	Urban fringe villages	Agricultural sub-prefecture centres	Commune seat villages	Small remote villages	One-way ANOVA	
Number of villages	26	37	122	254	F value†	Sig.‡
Cluster variables						
Population size	1025	2642	1479	682	652.2	<0.001
Pop density 2.5 km	929	386	220	166	175.1	<0.001
Infrastructure index	1.58	2.73	2.37	1.42	27.3	<0.001
Fraction non-ag pop.	29.9%	13.9%	13.3%	10.8%	16.9	<0.001
Near paved road	100%	78%	59%	54%	9.32	<0.001
Other variables						
Infrastructure level	0.46	1.16	1.06	0.53	29.4	<0.001
Pop density 1 km	1959	1299	730	384	121.7	<0.001
Socio-economically homogeneous	0%	27%	28%	43%	8.92	<0.001
Ag household size	6.12	6.42	6.22	5.78	5.31	0.001
Non-ag household size	3.90	3.81	3.95	3.40	4.26	0.006
Avg. household size	5.29	5.94	5.83	5.47	3.92	0.009
Nearby latrine adoption rate	5.7%	4.6%	2.7%	2.8%	2.98	0.031
Proximity to A-B.	0.21	0.19	0.17	0.21	1.95	0.121
Far from any road	0%	11%	19%	20%	2.65	0.049
Urban commune	62%	24%	9%	13%	18.6	<0.001
% reduction non-ag from average household size	26.1%	34.7%	31.5%	32.5%	0.77	0.501
Piped water	0.69	0.65	0.13	0.13	11.4	<0.001
School	50%	92%	91%	51%	29.1	<0.001
Growth rate	0.015	0.080	0.040	0.016	15.3	<0.001
Latrine adoption variables						
Number of latrines	22.0	18.6	9.1	3.5	24.4	<0.001
Log (latrines)	2.71	2.09	1.46	0.86	31.3	<0.001
Any latrines (adoption started)	96%	76%	67%	48%	12.9	<0.001
Many latrines (>10) (strong demand)	62%	46%	20%	9.8%	24.0	<0.001

*From cluster analysis of the set of 439 villages with 63 'outliers' removed (see text).
†The non-central F value is the ratio of the treatment mean sum of squares to the error mean sum of squares.
‡Upper-tailed significance of the specified F value test of differences between groups.

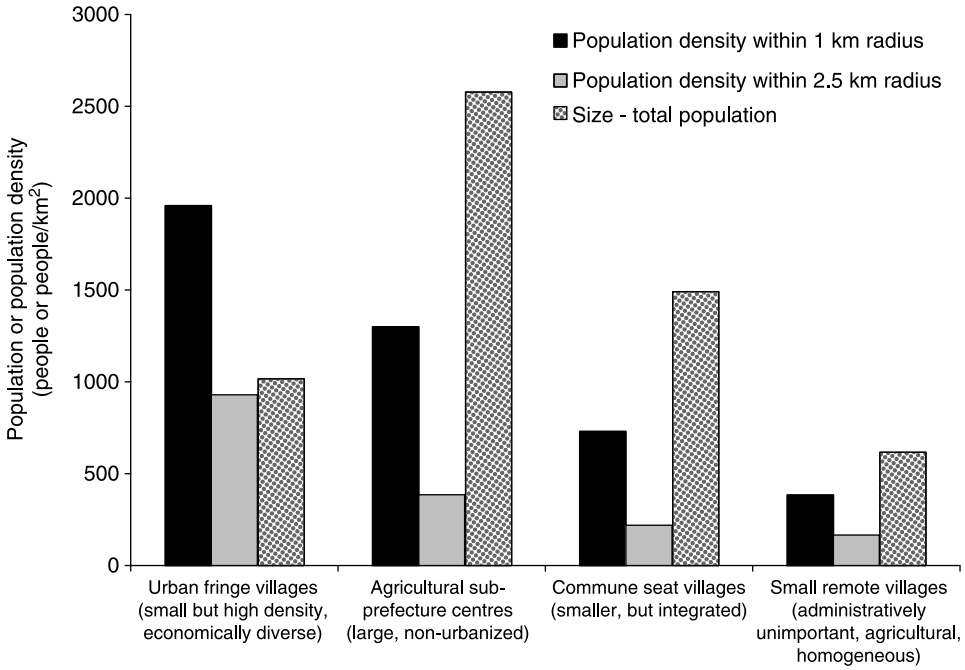

Figure 3 | 1993 Population and density characteristics of four village types in rural Benin.

associated with their large size and more important administrative and commercial roles for surrounding areas. However, occupations were oriented largely towards traditional agriculture, the non-agricultural household fraction being below average, population growth rates highest, and household size largest, suggesting wealthier but perhaps more traditional agricultural lifestyles (Kamuzora 2001). Between Type 1 and 2 villages, latrine

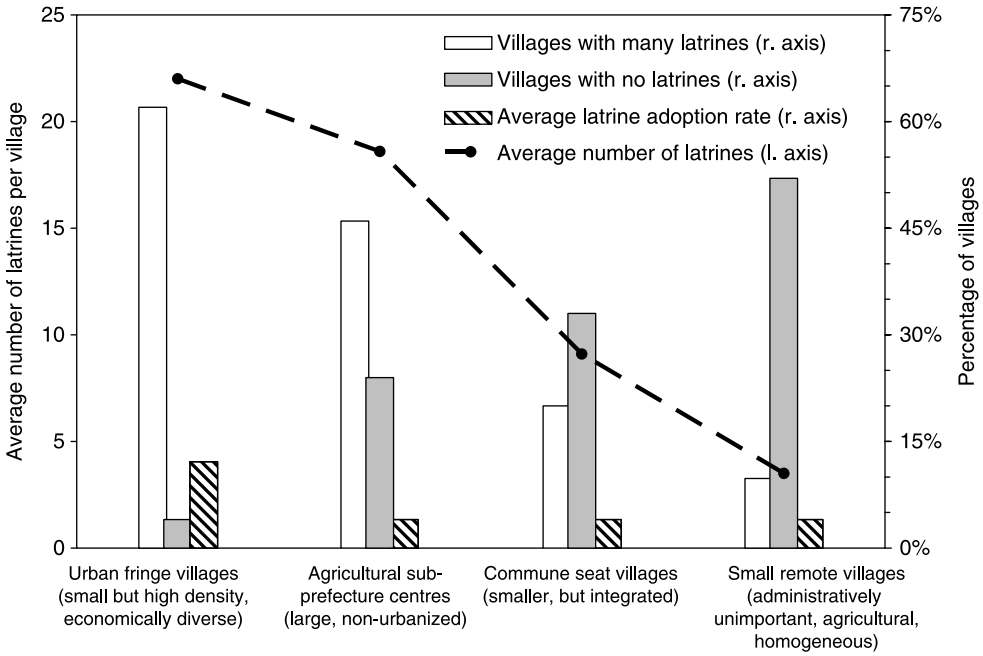

Figure 4 | 1993 Latrine adoption characteristics of four village types in rural Benin.

adoption rates dropped off sharply (Figure 4). Fewer than half had more than 10 latrines and one out of four had no adoption at all. However, Type 2 villages have many physical and social conditions (developed infrastructure, road access, population density, wealth, size, socio-economic diversity and so on) ripe for stimulating prestige and well-being goals for latrine adoption despite less favourable occupational lifestyles, and thus, the potential for achieving higher levels of adoption through increased latrine awareness and supply access. Type 2 villages represented about 20% of the 1993 rural Zou population.

Smaller and less dense villages than Type 2 comprise the third level in the geographic hierarchy of settlements in Zou. They are similar to Type 2 with regard to infrastructure and occupations, but with respect to population density, isolation, and local opportunities for latrine exposure, are more similar to Type 4, and lack the size and importance to be targeted for piped water supplies. This group made up the largest fraction (38%) of 1993 Zou rural population. The proportion of villages with more than 10 latrines drops off sharply between Type 2 and 3 villages, although the overall rate of adoption, around 3 to 4%, is similar. Type 3 villages have less of the physical and social environment conditions that arouse more broadly perceived well-being drives for latrines, than Type 2. Existing demand in these villages is thought to be generated mostly by individual lifestyle factors whose limited presence in the more agriculturally homogeneous and remote villages among this group has the potential to constrain the 'maximum level of penetration' of latrine adoption in Type 3 villages (Gatignon & Robertson 1985).

The group of isolated, small, homogeneous, agricultural villages with the lowest population densities, lowest proportion of non-agricultural households, little or no infrastructure, greater poverty (as suggested by the smallest average agricultural household size), and least likelihood of having a school comprise Type 4. The few non-agricultural households living in these villages tended to be much smaller than average size, suggesting households with very divergent modern lifestyles from those of their agricultural neighbours. Type 4 villages constituted the largest number of villages and about 36% of the 1993 rural Zou population. Because these lack most of the village environment and individual lifestyle factors involved in current motivation to adopt, they could have the least favourable conditions for successfully stimulating household desire and investment in a latrine. Latrine exposure is also much lower, as demonstrated by the low percentage of these villages with adoption initiated.

Regional approaches to demand-led sanitation promotion and supply-side development

Regional strategies for sanitation promotion, based on the above analyses, are proposed and, while based on an analysis of latrine adoption diffusion in Zou Department, have relevance to similar rural settings across sub-Saharan Africa.

Create strategically located Type 2 diffusion centres

Type 2 villages rating high on conditions associated with higher latrine adoption levels could be turned into new local diffusion centres, taking advantage of their hierarchical position and spatial location, to increase local latrine exposure opportunities and awareness in their areas of influence. Activities aimed at raising adoption within selected Type 2 villages, through developing supply chains and promoting desirable latrine designs based on perceived desires for change, could be followed by creating and expanding structures to support latrine promotion in outlying Type 3 and 4 villages with the most favourable demand-stimulating village environment conditions, once adoption had accelerated sufficiently in selected Type 2 diffusion centres. A sequenced package of appropriate latrine designs, technical services, publicity, information campaigns, and construction advice would need to be developed and delivered, based on dominant motivations for installing a latrine in surrounding villages.

Remove implementation-related constraints in Type 1 villages

Type 1 villages have high latent demand created by favourable village environment and lifestyle characteristics that stimulate well-being and prestige desires for latrines. These villages should be the focus of supply-side and support activities to reduce or remove commonly encountered

implementation-related constraints that block latrine adoption (Jenkins 2004; Jenkins & Sugden 2006), achieving high coverage levels in Type 1 villages, as opportunity and ability constraints are reduced. Type 1 villages offer the fastest and greatest potential for rapid increases in community-level improved sanitation through latrine adoption.

Exploit urban–rural linkages

Existing urban–rural linkages, especially private (social and family) and professional (occupational and educational), provide a potentially effective channel for publicity, consumer education and latrine information dissemination, as well as access to latrine construction support activities and suppliers. Preferential use of urban–rural linkages might be particularly appropriate among Type 1 villages that already have high awareness and potential for stimulating desires for latrines, but where access to quality services and support for latrine design and construction is likely to be lacking. This strategy may also work well for Type 2 and 3 villages better integrated economically and regionally with larger urban centres.

Address higher priority problems in Type 4 villages

This analysis suggests resources could be wasted on sanitation promotion in Type 4 villages, and effort better spent addressing higher priority problems such as education, roads, household water supplies, agricultural extension and preventive health services for which Type 4 populations are likely to feel a real need and be more willing to pay. In the longer term, investment in these services is likely to modify village environments and lifestyles in ways that arouse motivations for latrines in the future. This observation aligns closely with the assessment of rural demand and willingness-to-pay for improved water supplies in very small and remote dispersed villages (World Bank Water Demand Research Team 1993). Alternatively, the community-led total sanitation (CLTS) methodology which uses shame and disgust to create village-wide social agreement and sanctions to stop open defecation and peer pressure to trigger construction of simple do-it-yourself pit latrines (Kar 2003) is an experimental approach that may suit the small size, isolation and occupational and social homogeneity that underlie the very weak latrine demand characteristics of Type 4 villages.

IMPLICATIONS FOR DEMAND-LED PROMOTION

This research revealed a number of important drivers related to village environment, lifestyles and latrine exposure that underlie observed divergent levels of household latrine adoption and diffusion among villages in rural Benin, confirming earlier research identifying factors associated with non-subsidized household latrine adoption in Benin and elsewhere (Jenkins & Curtis 2005; O'Loughlin *et al.* 2006). Without motivation to change defecation practices and install sanitation, removing implementation barriers for households (e.g. provide access to products and services) or reducing costs (e.g. subsidize hardware) is unlikely to increase effective demand for improved sanitation. Several novel demand-led strategies to increase rural adoption of improved sanitation in low coverage areas are suggested from this analysis of latrine adoption and diffusion patterns at village level over a large area of Benin.

- Begin by targeting villages with high levels of the necessary village environment and/or lifestyle conditions for arousing desires for adopting latrines (Type 1 and some Type 2 villages). These conditions provide the foundation for stimulating latent demand when sufficient awareness is created, and are indicated by increasing population density, larger size, increasing fraction of non-agricultural occupations, socio-economic diversity, infrastructure development, and so on.
- Village environment conditions (physical and social) may broadly affect well-being desires for latrines despite individual lifestyle differences. Deeper study of how they stimulate demand should reveal several common and widely appealing promotional messages about broadly shared advantages of having a latrine in similar village environment conditions.
- Presence of households with non-agricultural occupations indicates an important lifestyle factor stimulating demand. This finding supports similar findings that non-agricultural households are more likely to adopt latrines (Jenkins & Curtis 2005; O'Loughlin *et al.* 2006). Focusing initially on non-agricultural households as innovators

and early adopters is a potentially efficient way to increase nearby latrine exposure opportunities and stimulate contagious adoption.

- Lifestyle factors such as increased mobility and urban social linkages associated with adoption can be expected to increase with proximity to a major road and to urban centres. Promoting latrines by focusing on desires aroused by travel (e.g. expression of new experiences and lifestyles, convenience and comfort) and urban social linkages (e.g. affiliation with the urban elite, modernization) could be effective in villages closer to roads and major urban centres (Jenkins & Curtis 2005; O'Loughlin *et al.* 2006).
- This analysis reveals how important local opportunities for *private* latrine exposure are for stimulating latrine adoption in a village. A capital-intensive investment such as a latrine is intrinsically unsuitable for trial purchase, so that creating and enhancing local opportunities for private latrine exposure and learning should be an important cornerstone of promotional strategies.
- Segmenting rural communities based on their demand characteristics provides a strategic basis for developing targeted promotional approaches, policies and resources, and for developing latrine technologies and supply chains that recognize and are tailored to the underlying differences in sanitation demand characteristics of communities. It allows a more strategic, demand-based, programmatic approach to sanitation development investment aimed at accelerating access to improved sanitation in low coverage rural areas. Interesting parallels to the typology of villages for demand-led rural water supply policies developed by the World Bank Water Demand Research Team (1993) emerge in this analysis of village sanitation demand characteristics, although the approach used here to develop village types for sanitation demand is quite different.

CONCLUSION

This research demonstrated how village-level secondary data necessary for regional analysis of latrine demand can be obtained from existing regional and national databases even in very poor developing countries in Africa. Insight into the underlying drivers of rural demand for sanitation in areas where household coverage is low can be gained from such analyses and used to target resources and develop suitable strategies better matched to the demand characteristics of villages in planning more coherent regional programmes for improving sanitation.

REFERENCES

Alihounou, E., Capo-chichi, V. & Kanhonou, L. 1995 *Projet de Recherche Operationnelle sur les Comportements d'Hygiène, Rapport Diagnostic de la Situation de Base (Phase I)*. UNICEF Cotonou, Benin.

Ben-Akiva, M. & Lerman, S. 1985 *Discrete Choice Analysis: Theory and Application to Predicting Travel Demand*. MIT Press, Cambridge, Massachusetts.

Cairncross, S. 1992 *Sanitation and Water Supply: Practical Lessons from The Decade*. Water and Sanitation Discussion Paper Series, No. 9, UNDP-World Bank Water and Sanitation Program, The World Bank, Washington, DC.

Cairncross, S. 2004 The case for marketing sanitation. *Sanitation and Hygiene Series Field Note*. Water and Sanitation Program–Africa, The World Bank, Nairobi, Kenya.

Cairncross, S., Blumenthal, U., Kolsky, P., Moraes, L. & Tayeh, A. 1996 The public and domestic domains in the transmission of disease. *Trop. Med. Int. Health* **1**(1), 27–34.

Curtis, V., Kanki, B., Mertens, T., Traore, E., Diallo, I., Tall, F. & Cousens, S. 1995 Potties, pits and pipes: explaining hygiene behaviour in Burkina Faso. *Soc. Sci. Med.* **41**(3), 383–393.

Frias, J. & Mukherjee, N. 2005 *Harnessing Market Power for Sanitation: Private Sector Sanitation Delivery in Vietnam*. Field Note, Water and Sanitation Program–East Asia Pacific, World Bank, Jakarta, Indonesia.

Gatignon, H. & Robertson, T. S. 1985 A propositional inventory for new diffusion research. *J. Consum. Res.* **11**(3), 849–867.

Hosmer, D. & Lemeshow, S. 1989 *Applied Logistic Regression*. John Wiley and Sons, New York.

INSAE (Institut National de la Statistique et de l'Analyse Economique) 1994 *Deuxième Recensement General de la Population et de l'Habitation Février 1992: La Population du Zou*. Ministère du Plan et de la Réstructuration Economique, Government of Benin, Cotonou, Benin.

Jenkins, M. W. 2004 Who buys latrines, where and why? *Sanitation and Hygiene Series Field Note*. Water and Sanitation Program-Africa, World Bank. Nairobi, Kenya.

Jenkins, M. W. & Curtis, V. 2005 Achieving the good life: Why some people want latrines in rural Benin. *Soc. Sci. Med.* **61**(6), 2446–2459.

Jenkins, M. W. & Scott, B. 2007 Behavioral indicators of household decision-making and demand for sanitation and potential gains from social marketing in Ghana. *Soc. Sci. Med.* **64**(12), 2427–2442.

Jenkins, M. W. & Sugden, S. 2006 *Rethinking Sanitation: Lessons and Innovation for Sustainability and Success in the New Millennium*. Commissioned thematic paper for the Human Development Report 2006, United Nations Development Programme, New York.

Kamuzora, C. L. 2001 Less poverty with higher household size in eastern and southern Africa region. Paper presented at the *24th IUSSP General Population Conference*, Salvador, Brazil 18–24 August 2001. International Union for the Scientific Study of Population, Paris, France, http://www.iussp.org/Brazil2001/s10/S10_02_Kamuzora.pdf (accessed 9 July 2009).

Kar, K. 2003 *Subsidy or Self-respect? Participatory Total Community Sanitation in Bangladesh*. IDS Working Paper 184, Institute for Development Studies, Brighton, UK.

Lafond, A. K. 1995 *A Review of Sanitation Program Evaluations in Developing Countries*. Environmental Health Project (EHP) Activity Report No. 5, United States Agency for International Development, Washington, DC.

Lorr, M. 1987 *Cluster Analysis for Social Scientists*. Jossey-Bass Inc., San Francisco.

Morrill, R. L. & Dormitzer, J. M. 1979 *The Spatial Order: An Introduction to Modern Geography*. Duxbury Press, North Scituate, Massachusetts.

Neter, J., Wasserman, W. & Kutner, M. H. 1990 *Applied Linear Statistical Models*, 3rd edition. Irwin, Inc., Homewood, Illinois.

Norusis, M. J. 1994 *SPSS Professional Statistics 6.1*. SPSS Inc., Chicago.

O'Loughlin, R., Fentie, G., Flannery, B. & Emerson, P. M. 2006 Follow-up of a low cost latrine promotion program in one district of Amhara, Ethiopia: characteristics of early adopters and non-adopters. *Trop. Med. Int. Health* **11**(9), 1406–1415.

Rogers, E. M. 1983 *Diffusion of Innovations*. The Free Press, New York.

Simpson-Hebert, M., Sawyer, R. & Clarke, L. 1997 *Participatory Hygiene and Sanitation Transformation*. World Health Organization, Geneva.

UNICEF 1997 *Better Sanitation Programming: A UNICEF Handbook*. Environmental Health Project No. 936-5994, United States Agency for International Development, Washington, DC.

Waterkeyn, J. & Cairncross, S. 2005 Creating demand for sanitation and hygiene through Community Health Clubs: a cost-effective intervention in two districts in Zimbabwe. *Soc. Sci. Med.* **61**(9), 1958–1970.

WELL 1999 *DFID Guidance Manual on Water and Sanitation Programmes*. Prepared by WELL for the UK Department for International Development, London.

World Bank Water Demand Research Team 1993 The demand for water in rural areas: determinants and policy implications. *World Bank Res. Obs.* **8**(1), 47–70.

Wright, A. M. 1997 *Towards a Strategic Sanitation Approach: Improving the Sustainability of Urban Sanitation in Developing Countries*. UNDP-World Bank Water and Sanitation Program, World Bank, Washington, DC.

First received 1 October 2008; accepted in revised form 21 April 2009. Available online 9 November 2009